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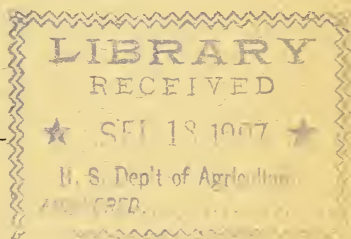
HAWAII AGRICULTURAL EXPERIMENT STATION,

JARED G. SMITH, SPECIAL AGENT IN CHARGE.

U. S. Department of Agriculture

ANNUAL REPORT
OF THE
HAWAII AGRICULTURAL
EXPERIMENT STATION
FOR
1906.

UNDER THE SUPERVISION OF
OFFICE OF EXPERIMENT STATIONS.
U. S. DEPARTMENT OF AGRICULTURE.



WASHINGTON:
GOVERNMENT PRINTING OFFICE.
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[Under the supervision of A. C. TRUE, Director of the Office of Experiment Stations,
United States Department of Agriculture.]

WALTER H. EVANS, *Chief of Division of Insular Stations, Office of Experiment Stations.*

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LETTER OF TRANSMITTAL.

HAWAII AGRICULTURAL EXPERIMENT STATION,
Honolulu, Hawaii, April 1, 1907.

SIR: I have the honor to transmit herewith and to recommend for publication the Annual Report of the Hawaii Agricultural Experiment Station for the fiscal year 1906.

Respectfully,

JARED G. SMITH,
Special Agent in Charge.

Dr. A. C. TRUE,

Director Office of Experiment Stations,

U. S. Department of Agriculture, Washington, D. C.

Publication recommended.

A. C. TRUE, *Director.*

Publication authorized.

JAMES WILSON,

Secretary of Agriculture.

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ANNUAL REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION FOR 1906.^a

SUMMARY OF INVESTIGATIONS.

By JARED G. SMITH, *Special Agent in Charge.*

The Hawaii Experiment Station has continued the policy of devoting its energies toward the diversification of agriculture in the Hawaiian Islands. During the period that has elapsed since the establishment of the station a number of agricultural industries have been begun or placed on a paying basis. Pineapple growing has been extended to include many large tracts, sisal production has been shown to be profitable, and tobacco raising has been demonstrated as practicable. In all of these enterprises the station has had a part, and the tobacco industry when developed will owe its inception to the investigations of the station.

Considerable work has been done in bringing more of the station land under cultivation in anticipation of the new water system provided for by Congress. About 10 acres of the lower portion of the station tract were cleared, fenced, plowed, and prepared for planting. As the station does not expect to plant all this at present, half the tract was cleared by the Territorial department of public works for the privilege of growing forage plants for a few seasons. In this way the station was relieved of the expense of removing a dense growth of lantana and guavas. The trial grounds of the station were completely fenced and a new slat greenhouse was constructed for the use of the horticulturist. A new stable was erected and a considerable amount of water pipe laid. An additional area, amounting to about 2 acres, on the higher portion of the station grounds was cleared and terraced by Japanese tenants at no expense to the station. The office and laboratory equipments were increased and numerous additions made to the station library by purchase, exchange, etc., so that now the station possesses the best collection of reference books on economic agriculture in Hawaii.

^aThis is the sixth annual report of this station. Previous reports will be found in U. S. Dept. Agr., Office of Experiment Stations Ann. Rpts. 1901, pp. 361-379; 1902, pp. 309-330; 1903, pp. 391-418; and 1904, pp. 361-382, and Bul. 170. A preliminary report on the agricultural resources and capabilities of Hawaii was published as Office of Experiment Stations Bul. 95.

FIELD WORK AND PLAT EXPERIMENTS.

POTATOES.

An attempt was made to demonstrate the possibility of growing early potatoes for the local market. About one-half an acre of land newly cleared of guava and lantana was planted to potatoes early in January, 1906. The plants were severely attacked by a form of rot and a very short yield was obtained. The crop was readily disposed of as new potatoes at 5 cents per pound, and the demand far exceeded the supply, thus demonstrating the presence of a local market capable of considerable development.

ROSELLE.

An experimental planting of roselle (*Hibiscus sabdariffa*) has been made each season for several years to demonstrate the value of this fruit for preserving, and to study methods of cultivation, insect enemies, and diseases. About one-fourth of an acre was grown this year, and a larger planting was made to carry the experiments through the coming year and to provide material for dissemination.

COTTON.

Several varieties of cotton were grown experimentally at the station during the past year, namely, Peruvian, from seed received from Mr. T. F. Sedgwick, formerly connected with the station, Carolina Prolific, Excelsior, Extra Long Staple, Sea Island, Russell Big Boll, Texas Bur, and King. The yield of the Upland varieties was not especially promising, but for the Peruvian and Sea Island the quality was good and the yield large. Samples of the different lots were submitted to the experts of the United States Department of Agriculture at Washington, and Mr. E. B. Boykin reported upon them as follows:

No. 1, Peruvian, seed from T. F. Sedgwick.—The length of lint of this specimen ranges from $1\frac{1}{8}$ to $1\frac{5}{8}$ inches; strength good; uniformity poor, the fibers very coarse to very fine, showing great variability in this respect. The drag is very strong, showing that the fibers are very crinkly, and should therefore possess good spinning qualities. The covering on the seed is remarkably heavy, indicating a very high per cent of lint. One fact which detracts from the value of this specimen is the very great variability in length and fineness of lint. Some locks are almost equivalent to the fineness of Sea Island, while others are no better than very ordinary Upland. It seems to afford an excellent opportunity for improvement by selection.

No. 2, Carolina Prolific.—Length of fibers from $\frac{3}{4}$ to 1 inch; uniformity fair; fineness medium; drag weak; strength poor; covering poor. This specimen should be classed as a rather poor Upland variety.

No. 3, Excelsior.—Length $\frac{3}{4}$ inch to $1\frac{1}{8}$ inches; strength fair; uniformity very good; drag weak; fibers coarse; covering fair. This should also be classed as ordinary American Upland short staple.

No. 4, Extra Long Staple Sea Island.—Length of fiber $1\frac{1}{2}$ to 2 inches; strength excellent; uniformity good; fineness excellent; drag strong; covering poor. The lint in this case is unusually fine. It seems to be quite as good as Sea Island.

No. 5, Russell Big Boll.—Length 1 to $1\frac{1}{2}$ inches; strength poor; uniformity fair; fineness very poor; drag fair; covering fair. This should be classed along with some of the poorest short-staple varieties. The extreme coarseness of its lint is a very serious defect.

No. 6, Texas Bur.—This sample is very similar to No. 2, and can only be classed as an ordinary Upland.

No. 7, King.—Length $\frac{3}{4}$ to 1 inch; strength poor; uniformity fair; fineness very poor; drag weak; covering fair. This sample is an American Upland variety which is noted for its short, coarse lint, and which is adapted to the manufacture of coarse goods only.

THE ORCHARD.

An orchard of tropical fruit trees, including mangoes, avocados, bread fruit, cherimoyer, sapodilla, wi, custard apple, longan, and others, has been planted and will be extended as rapidly as seedlings or valuable varieties can be obtained. A nursery of citrus stock has been established to provide material for budding and grafting. The uncertainty of the station's water supply has in the past made permanent plantings impossible, but with the special appropriation provided by Congress it is believed that a supply of water will be developed sufficient to care for all the fruit trees planted on the lower portion of the station grounds.

MISCELLANEOUS.

Plantings have been made of about 4 acres of coffee and rubber trees on the middle portion of the station reservation and about 1 acre of coffee on the upper Tantalus ridge.

About 200 cuttings of vanilla were placed in a grove of Keawe. The plants have rooted nicely and may be expected to begin to bear in a year or more.

The Bluefields bananas that were imported by the station several years ago have been extensively propagated and about 1,000 suckers have been distributed among some fifty growers, and already very favorable reports concerning them have been received. As these bananas are now quite widely distributed, the station will not continue their propagation on as large a scale as formerly.

In January, 1906, 265 pounds of grass and other forage plant seed, collected on the ranges of southern Arizona, New Mexico, and elsewhere, was distributed to about fifty members of the Hawaiian Stock Breeders' Association. The collection included seed of white grama, gray weed, Japan fodder, winter orchard rye, side-oats grama, Spanish sulla, sainfoin, *Paspalum dilitatum* from Australia, and other varieties. Many of these grasses and forage plants are now well established on some of the island ranches, and it is believed that they will aid materially in restocking the ranges that have been over-pastured.

A collection of limus, or edible seaweeds, was made in the shallow waters of the islands, and chemical studies and cooking experiments

performed with them in order to determine the extent to which it might be profitable to revive a former Hawaiian industry in these plants. The seaweeds which supply the agar-agar and Irish moss of commerce are fairly abundant in the island waters about Hawaii, and there appears to be no insurmountable difficulty against building up quite a local industry in the preparation of these marine food plants.

COOPERATIVE WORK.

GRAPES.

The growing of grapes has been followed to a limited extent in Hawaii for many years, but has never become what might be called an industry in any sense. On the island of Maui a rather extensive cooperative experiment in growing wine grapes has been begun. One hundred and seventy-seven varieties of wine grapes were planted by the station horticulturist in March, 1906, and the further expense of the investigation is to be paid by the owners of the vineyard. The growing of table grapes is carried on to a limited extent by some of the Portuguese settlers and others (Pl. I, fig. 1), and with the anticipated increase of immigrants from Spain, Portugal, and the Azores it is believed that grape growing and wine making will become profitable industries.

RUBBER.

An important experiment in rubber production has been begun at Nahiku, Maui, in cooperation with a rubber company. The growing of rubber-producing trees in Hawaii is not of recent introduction, as isolated trees of a number of the best known varieties are to be found here and there and in some places small groves exist that have suffered more or less from neglect. A number of companies have been recently organized for producing rubber, and the one cooperating with the station has set apart $1\frac{1}{2}$ acres of land planted to rubber trees for experiments with fertilizers, variety tests, methods of tapping, preparation of rubber for market, etc. The difficulty of obtaining seeds of rubber trees and the low vitality of some shipments will make the extensive development of this industry rather slow. The station is cooperating with the Territorial board of agriculture and forestry in securing seed of the better known varieties. The question of growing the trees does not need demonstration, but the economic production of rubber remains to be investigated. One or two small groves of Ceara rubber trees large enough for tapping purposes have been located, and arrangements have been made to conduct careful experiments to determine the yield of these trees (Pl. I, fig. 2). These experiments will be extended as opportunity offers.



FIG. 1.—GRAPES GROWING AT HONOLULU.

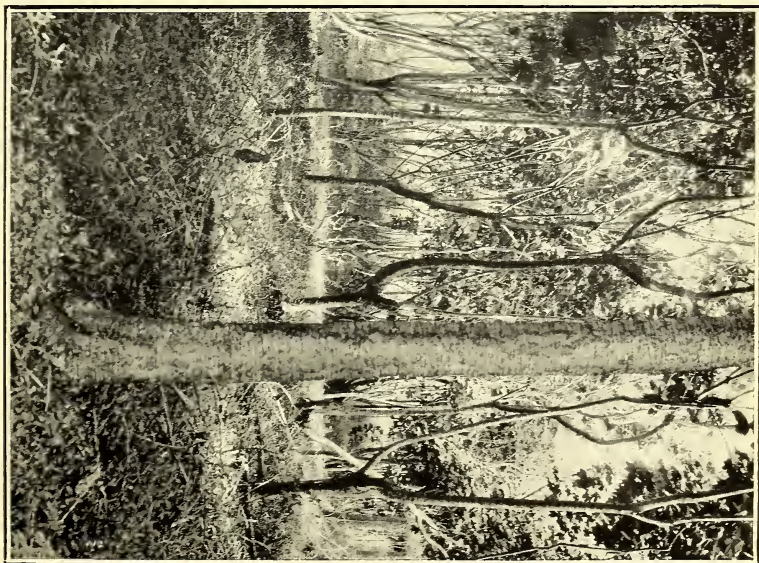


FIG. 2.—GROVE OF SEVEN-YEAR-OLD CEARA RUBBER TREES.

TOBACCO.

The tobacco investigations carried on by the station are in cooperation with the Territorial board of agriculture and forestry, assisted by contributions from a number of individuals. The experiments with tobacco were begun in 1904, and in October, 1905, the first samples of Hawaiian-grown tobacco were submitted to expert judges for examination. Samples were sent to all parts of the mainland, and about 150 pounds were made up into cigars for distribution in Hawaii. The experts who examined the tobacco leaf are of the opinion that it is of good burn and flavor and that the elasticity, firmness, and general texture place all of the samples in the wrapper class.

The quality of the leaf is due to the soil and climate. The tobacco belt of Hamakua is coincident with that portion of the mountain slopes where the clouds gather almost every day in the year. The mornings are usually clear, with full sunshine, but before the heat of midday clouds drift in from the ocean and rest over the lower slopes, disappearing again toward evening. In effect the Hamakua tobacco is shade-grown, not by virtue of being planted under cloth tenting, but because of Mauna Kea's fog bank. It is a tenting that is rolled over the fields by nature's hand.

In February, 1906, a crop was planted on lot 17 Paauilo Homestead, this tract of 110 acres having been set aside by the Territorial commissioner of public lands for the use of the station for a period of three years. Five acres of abandoned coffee were cleared, part of the land plowed, and the balance merely hoed. Seed beds were started, and as rapidly as plants could be obtained these were transferred to the fields. The field work was begun so late that the cost was much greater than it should have been. Lumber was purchased, and a curing barn large enough to care for the crop of 5 acres was erected; but even with all the expedition the house was not ready in time to care for the first of the crop, and, as in previous years, a part was lost through its becoming overripe. The tobacco work for 1906 cost about \$6,000, half of which was subscribed by three citizens of Hawaii.

The completion of the fiscal year 1906 thus saw a substantial beginning toward a trial of tobacco on a field scale. The tobaccos growing at that date were Sumatra, Turkish, Cuban, and various seed-leaf strains from Connecticut, Pennsylvania, and other tobacco-producing States. While the crop is not yet finished, the fermentation process not being completed, it has been pronounced by many experts to whom samples of the tobacco were submitted as of as good quality as any tobacco produced anywhere in the world. A German manufacturer who examined samples of our 1905 tobacco stated that in his opinion the Hamakua leaf is unexcelled in burning qualities, being superior in that respect to most mainland varieties, and that the mild flavor places it on an equality with the best Brazilian and some Cuban sorts.

A Philadelphia leaf buyer stated that the samples submitted to him were worth as filler 20 cents per pound unsorted. Small samples of wrapper were variously priced according to style and color at from 50 cents per pound up to \$4.50 per pound.

The results of the 1906 crop are such that it will hardly be necessary to attempt any further demonstration on a field scale, but there are many points connected with the curing, fermenting, and sorting, and with the treatment of the plants in the field, on which the station could do good work, provided arrangements can be made to carry on such work in cooperation with growers. It has been demonstrated absolutely that tobacco of good burn, texture, flavor, and color can be produced on a commercial scale and probably at a very large profit in certain districts in Hawaii.

COFFEE.

In January, 1906, the special agent in charge of the station was requested by some of the coffee growers on the island of Hawaii to visit Washington, D. C., to work on their behalf in favor of the coffee industry, which is much in need of relief.

The coffee industry is one especially adapted to the development of a stable population of small landowners. The coffee belt lies at an elevation of from 1,000 to 3,000 feet, the most salubrious location in the islands, a region of comfortable temperatures the year around. Coffee does not require a large outlay of capital in its cultivation, and it is a crop which can be prepared for market without expensive machinery. When once prepared, it does not deteriorate, but, on the contrary, constantly improves with age, so that the producer is not subject to the great losses which frequently happen to those engaged in the production of perishable crops. There are no difficulties about growing coffee in Hawaii. The trees are remarkably free from disease, the yields are high, and returns sure. Coffee is a cash crop which can be drawn against as soon as a single bag is started on its ocean journey to the market. The chief cause of failure as regards coffee growing in Hawaii is due to economic conditions. The best grades of Hawaiian coffees have always been in demand, and these grades sell themselves. The low grades, however, can not be produced in competition with Brazil and similar countries, and practically every small producer engaged in coffee growing in Hawaii has been forced out of business (Pl. II, fig. 1). A few of the larger growers who remained have managed to continue only through the exercise of the most vigilant care and economy, and have held on more because they had faith in the future than on account of actual profits returned upon their investment.

Another factor affecting the coffee situation is that the character of the coffee trade as a whole is changing. The bulk of the coffee now

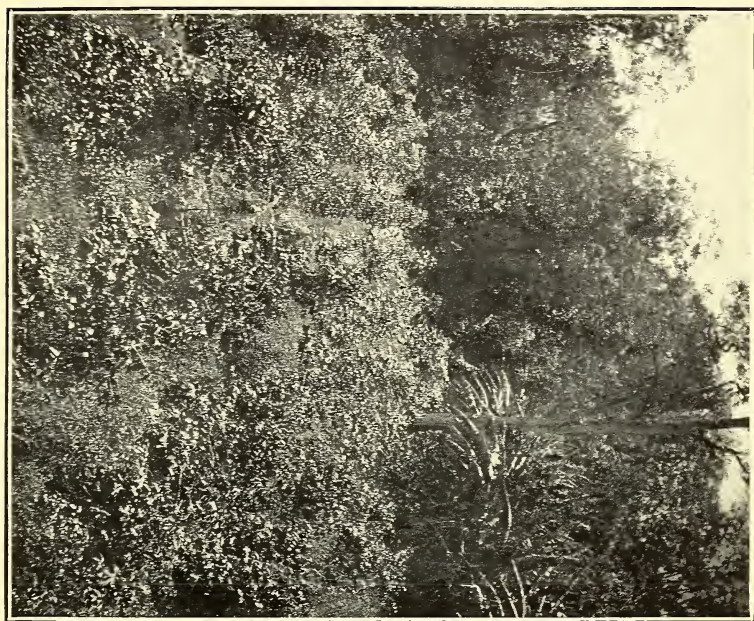


FIG. 1.—ABANDONED COFFEE, OLA.

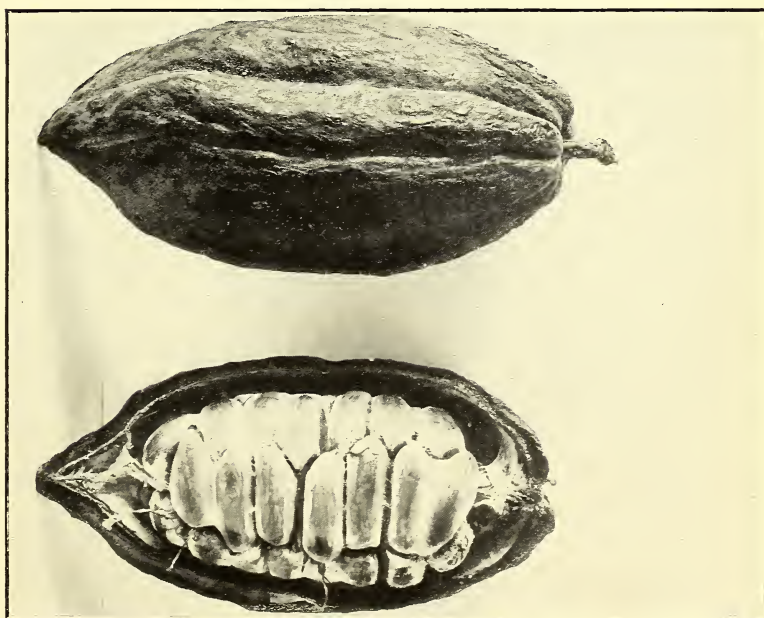


FIG. 2.—THE SANGOAN CACAO.



purchased by the consumer has been roasted or roasted and ground. This practice lends itself to the substitution of low grades for high grades, especially when coffee already ground is placed on the market. It is believed that a considerable quantity of coffee that under the old conditions would be unsalable is worked over and mixed with good grades in the so-called "package" coffees.

RICE.

Rice was formerly one of the important Hawaiian crops, but the industry has been in a bad way on account of increasing competition with rice from Japan, Louisiana, and Texas, and to some extent through the deterioration of the local product as well as the expensive methods of cultivation. Through the generous cooperation of several prominent estates a series of experiments was begun by the Hawaii station to determine what improvements in methods of cultivation, harvesting, fertilization, milling, breeding, and selection could be introduced to bring about the rehabilitation of the industry. Mr. F. G. Krauss, formerly in charge of the agricultural work of the Kamehameha schools, was secured to have this work in charge, and the lines of investigation planned embrace rice culture, breeding, and fertilization, and rotation of crops. Through the cooperation of the Bureau of Plant Industry of the Department of Agriculture 150 varieties of rice were obtained from different parts of the world for trial in comparison with the local varieties. These experiments have not progressed far enough to report definitely upon them, but it is believed that by improved methods of culture, the introduction of modern machinery, and the improvement of varieties it would be possible to restore rice growing to its former important position.

CACAO AND BANANAS.

The cooperative experiments with these two crops on the grounds of the Hilo Boarding School have been continued. Important collections of varieties of these plants, especially cacao (Pl. II, fig. 2), are desirable, and will be extended as rapidly as possible. The growth of the cacao during the past year was decidedly unfavorable, the poor results being attributed in a large degree to an unusual drought in a region which is generally considered as having exceedingly heavy rainfall. The bananas planted for shade have grown well and some varieties have fruited, so that the experiments can not be considered a failure, even though the results with cacao have not been very flattering.

CHEMICAL INVESTIGATIONS.

The work of the chemist has been divided between ordinary routine work and research investigations. Prominent in the routine work has been the completion of the analyses of some of the more important Hawaiian fodders and feeding stuffs, the results of the investigation

having been published in Bulletin 13 of the station. The most important result of this work was the establishment of the fact that many Hawaiian-grown fodders contain insufficient lime for the needs of live stock. Considerable interest on the part of stockmen has been shown in this work, and the feeding of bone meal with the other rations or mixed with salt is being practiced by some of them. Studies were made of a number of samples of soils to determine their adaptability for tobacco growing. Another line of work that seemed to offer opportunities for development was the utilization of various by-products as sources of alcohol. Studies were made of a number of these, among them the waste from pineapple canneries, bananas, ti root, etc., to determine their value for fermentation and distillation.

The research work was mainly along the same lines of investigation as those described in previous reports, namely, a study of the nitrogenous compounds in Hawaiian soils. These investigations have been carried forward to such an extent that the chemist has prepared a first report on them, which is given elsewhere (see p. 37). Some studies were begun on the manganese content of some of the soils of Hawaii, samples from Wahiawa, Oahu, containing as much as 10 per cent of that substance. A portion of the chemist's time was devoted to making dietary studies to determine the nutritive value of some of the foods used in Hawaii.

ENTOMOLOGICAL INVESTIGATIONS.

The station entomologist has devoted considerable attention to the preparation of a card catalogue of the literature relating to economic entomology of Hawaii and in extending the collection of insects of economic importance. The investigations carried on by him have been along lines of the control of insect depredations, of silk culture, beekeeping, and mosquito control. In cooperation with the station chemist studies were made of Hawaiian honeys to determine the sources from which they were gathered. Two new races of bees have been introduced during the year, and one gives promise of being better suited to Hawaiian conditions than the Italian bees now reared. The enemies and diseases of bees are being studied, with a view to including these topics in a contemplated report on the bee industry in Hawaii.

The silk work was along very much the same line as that described last year. Through the cooperation of the Bureau of Entomology of the U. S. Department of Agriculture, a quantity of eggs of the Oro race of silkworms was obtained and bred for comparison with the races previously reared. A detailed report of these investigations will be found elsewhere (p. 19).

The entomologist continues to act with the local committee in attempting to control the spread of mosquitoes about Honolulu. During the past year the most important work along this line was the successful

introduction of surface-feeding minnows to feed on the mosquito larvæ in fish ponds, taro fields, rice fields, and other places where draining and spraying are impracticable. A full report on their introduction is given on another page (p. 25).

HORTICULTURAL INVESTIGATIONS.

The horticulturist, in addition to caring for the nurseries and orchards and extending the collections as rapidly as possible, is devoting especial attention to the marketing of tropical fruits. Trial shipments of avocados were made to New York City in 1905 and other lots were successfully sent in cold storage on some of the army transports to Guam and Manila. Following the successes with these preliminary shipments, in June, 1906, preparations were made for an experiment with larger lots of pineapples, avocados, papayas, and bananas, and in August a shipment of about six tons of these fruits was made to San Francisco, accompanied by the horticulturist. The fruits were packed in various ways to determine the best method of commercial handling, and observations of the fruit were made between Honolulu and San Francisco to learn some of the transportation problems of the ocean voyage. A number of cities on the Pacific coast were visited and the fruits exploited. The tests were highly satisfactory, and it is believed that enlarged markets for these fruits are assured whenever regular supplies can be secured.

In this connection one of the first matters taken up in 1906 was that of a fruit-marketing association. Such an organization would enable the producer to secure more favorable selling prices, and it would also result in more regular supplies of fruit of uniform character. Considerable correspondence was carried on by the horticulturist with various fruit growers and shippers in the Hawaiian Islands with a view to the formation of such an association. While no definite results have as yet been obtained, it is believed that such an organization will shortly be formed.

PUBLICATIONS.

During the year the station issued the following publications:

Bulletin No. 11. The Black Wattle in Hawaii, by Jared G. Smith.

Bulletin No. 12. The Mango in Hawaii, by J. E. Higgins.

Bulletin No. 13. The composition of some Hawaiian Feeding Stuffs, by E. C. Shorey.

Press Bulletin No. 15. Lime an Essential Factor in Forage, by E. C. Shorey.

Press Bulletin No. 16. The Avocado Mealy-Bug, by D. L. Van Dine. This is an enlarged and revised edition of Press Bulletin No. 8, the supply of which had become exhausted.

In addition to these publications, the special agent in charge and various members of the staff have contributed articles along agricultural lines to the Hawaiian Forester and Agriculturist and the local press.

REPORT OF THE ENTOMOLOGIST.

By D. L. VAN DINE.

As the entomological investigations of the station have progressed, certain lines have developed sufficiently to make a classification of the work possible. The more important lines are the injurious insects of the islands and their control; mosquitoes and their control; silk culture, and beekeeping. Along with these definite lines of work there is an amount of routine and miscellaneous work not easily classified. As heretofore, the entomologist has worked without an assistant, and would urge such an appointment as needful to the increasing demands made upon the station staff in general and the consequent development of this phase of the station work. A good equipment and working library are now at hand.

The correspondence is of a more satisfactory nature than during the first years of the station's existence. More cooperation is manifested in the problem of determining the sources of insect injury and the question of their suppression. This is due to a better understanding of the principles of insect control and the use of insecticides.

The work on the collection and records has been somewhat neglected during the past year and necessarily so in the face of more pressing duties. A permanent start has been made, however, and both phases of the work will receive more consideration when additional assistance is forthcoming. The collection of Coccidæ is especially complete, mounted in Riker mounts in connection with their food plants for exhibition purposes.

Aside from the annual report for the last fiscal year, the entomologist has published press bulletins Nos. 14 and 16 of the regular station series on Fuller's rose beetle (*Aramigus fulleri*) and the avocado mealy-bug (*Pseudococcus nipæ*), respectively. Many articles have also been supplied the local press and The Hawaiian Forester and Agriculturist on subjects relating to the entomological work of the station.

The field work has, as formerly, occupied a large amount of time. It is imperative that an intimate knowledge of the conditions in the varying localities of the islands be obtained at first hand to satisfactorily solve the problems that present themselves in carrying out the various projects. Many trips were made about the island of Oahu and one to the Hilo district, island of Hawaii, in the distribution of the top-minnows, which are discussed under the subject of mosquito control. One trip was made to the Nahiku district, island of Maui, to make an entomological inspection of the newly established rubber plantations in that locality. One trip was made to the Kohala district, island of Hawaii, in a survey of the insects injurious to field crops other than sugar cane on the homestead lands of that district.

Repeated trips were made to the outlying districts of Honolulu in the study of beekeeping and the distribution and life cycle and habits of the mango weevil (*Cryptorhynchus mangiferæ*).

The entomologist acknowledges gratefully many courtesies from colleagues throughout the country and abroad and would mention the help received from Dr. L. O. Howard and the other experts of the Bureau of Entomology in determinations of specimens and investigations in silk culture and beekeeping.

SILK CULTURE.

REPORT OF COCOONS GROWN IN 1905 EXPERIMENT.

Under date of November 6, 1905, the following letter was received from the Bureau of Entomology, United States Department of Agriculture:

DEAR MR. VAN DINE: In the temporary absence of Dr. L. O. Howard, I have to answer your letter of the 8th ultimo, which was received some time since, but has been held pending the arrival of the cocoons. These cocoons have just come to hand and are in excellent condition, and are well worthy of being graded as first-class. They are not, however, as firm as some specimens of Sferici cocoons received this season, yet are very superior to many others which have come to our notice. I think this lack of firmness is not due to lack of care, but to the moisture-laden air of the islands; or, in other words, I think that the race is not well suited to your locality. Perhaps a Japanese race or a cross with a Japanese race would make a better cocoon. No reeling has yet been done to your cocoons, but I feel sure that a large percentage of floss or loose waste silk will result. We will advise you in this regard later.

So far as the price of cocoons goes, you must be aware that there is practically no market for them in the United States. We are trying to stimulate an artificial market by buying cocoons at from 90 cents to \$1.15 per dried pound. This is slightly above the current European price. We also pay transportation under certain conditions. Our ability to purchase cocoons depends entirely upon Congressional action and therefore it is impossible to say how long we can continue to buy cocoons. I inclose herewith for your information a circular on silk culture which we are sending out very extensively, which will give you some idea of the lines we are following.

Our supply of silkworm eggs for next season's distribution has not yet been received from abroad, so we can not send you an ounce of eggs at this time. However, we will send you an ounce in the spring, just as soon as it is safe to do so.

We will reel your cocoons and return the raw silk to you, but I regret we will be unable to weave any of it into cloth, as we have no machinery for this latter process.

Very respectfully,

C. L. MARLATT,
Acting Chief of Bureau.

Mr. D. L. VAN DINE,
Experiment Station, U. S. Department Agriculture, Honolulu, Hawaii.

Regarding the percentage of floss or waste silk resulting from the reeling mentioned in the above letter, Doctor Howard advised the writer under date of December 11, 1905, that "contrary to expectations, some of the results have shown a truly remarkable silk in many ways, especially in economy of reeling."

The detailed report on the cocoons was received under date of December 23, 1905, and is as follows:

DEAR MR. VAN DINE: I am returning you this day, by accompanying mail, the silk which has been reeled from your cocoons, less one skein, which was used in making tests. Please find inclosed a copy of a letter from Mr. James Chittick, secretary of the Clifton Silk Mills, Weehawken, N. J., relative to the qualities he found in your silk.

So far as your part is concerned the actual raising of the cocoons was certainly successful and you are to be congratulated with the splendid showing which they make. The strength and elasticity of the fiber and the very economical reeling results could not be bettered. Generally speaking it requires 4 pounds of dried cocoons to produce one pound of raw silk in the reeling; your cocoons produced 1 pound of silk to about 3 pounds of cocoons, which is equal to the most economical results obtained in experienced silk-producing countries. The weak places in the thread, causing numerous breaks, was entirely the fault of our reelers. Hairiness is due to the nature of the cocoon employed. We were well aware of this feature before sending you the eggs, but as the Sferici is a particularly hardy race and one safe to put into the hands of our inexperienced people, we have laid aside commercial qualities to some extent until a higher degree of proficiency should be attained by the producer and for this reason have distributed more eggs of the Sferici than of any other race. Commercially there is no comparison of this race with China and Japan silk. This feature is strongly brought out in the next phase—gumminess. Ordinarily the silk from your type of cocoon should have given a loss of 24 per cent in weight in the boiling-off process, due to the solubility of the gum. Actual tests showed a loss of 28 per cent, or 4 per cent in excess of the ordinary. This is no doubt due in great measure, if not entirely, to atmospheric conditions, and seems to show that the Sferici race, as stated in a previous letter, is not entirely suited to Hawaii. Japan silk loses 18 per cent and China silk 19 per cent in the boiling off.

In the eggs to be sent you in the spring I will try and select those of a race which seems better suited to Hawaii, though in this matter we must be guided mainly by experiment. Judging from results obtained in Hawaii between the years 1837 and 1842, by using a cross between the Canton white and yellow and the so-called American race, I am inclined to believe that by all means a cross race should now be used and that the Canton white or yellow be employed as a basis.

Yours, very truly,

L. O. HOWARD,
Chief of Bureau.

MR. D. L. VAN DINE,
Experiment Station, U. S. Department of Agriculture, Honolulu, Hawaii.

REPORT OF CLIFTON SILK MILLS.

THE CLIFTON SILK MILLS, POST-OFFICE, WEEHAWKEN, N. J.,
Town of Union, N. J., December 16, 1905.

Dr. L. O. HOWARD,

Bureau of Entomology, U. S. Department of Agriculture, Washington, D. C.

DEAR DOCTOR HOWARD: I beg to report on the Hawaiian silk as follows:

The silk seems generally to have good strength and elasticity. It seems in places to be rather irregularly reeled, the result being that in the winding it breaks much oftener than it should.

This skein broke seventeen times in the winding, whereas silks that we are regularly handling would not break more than three times at the most. Still, it is only fair to say that as this skein had been opened and examined by us before putting on

the winding, it might have fared a little better in this respect had it gone directly on the machine. There were, however, scattered through it, weak places.

The size of the silk we make to be about 14 deniers. To get a proper judgment we threw this into two skeins of organzine and boiled off one of the skeins. The boiled-off skein weighed 786 grains and after boiling off weighed 565 grains, a loss of over 28 per cent. One per cent of this might be accounted for by soap and oil, and possibly there may have been some atmospheric difference between the time it was weighed in the thrown state and in the time it was weighed in the boiled-off state.

As we are returning to you the skein of organzine not boiled off, you can make yourself exact determinations in this respect from the former.

We do not think that the soap and oil put in here will amount to more than 1 per cent, as previously stated.

On putting some of this boiled-off silk on the testing reel for examination (in which state you can form a sounder opinion than you can before boiling off), we find that it makes a very fair organzine, being quite regular, with a good deal of elasticity, and fairly brilliant.

The main criticism to be made of it is its hairiness, and this is due principally or entirely to the nature of the cocoons.

For comparison, we would say that it is very similar to an Ardeche classical silk. Ardeche ranks in about the second grade of Cevennes silk, and classical, as you know, is the second classification. This hairiness is common to all Cevennes silks.

By getting European quotation on the grade above referred to you will therefore be able to arrive at a fair idea of its commercial value.

The Piedmont, China, and Japan silks are, of course, not so hairy, and this hairiness would make this silk unsuitable for some purposes.

I would suggest that you would find it of interest to wind a little, both of the boiled-off and the unboiled-off, and by then winding them onto a testing reel you will be able to get an excellent idea of the points above referred to.

Referring to what you say in your letter of November 16, I would state that a return of 1 pound of silk for 3 pounds of cocoons is a first-class return.

If there are any other points that you would like to be advised about in connection with this, I shall be pleased to take them up with you.

Very sincerely, yours,

JAMES CHITTICK.

Regarding a market for dried cocoons, the following is quoted from the circular referred to in Mr. Marlatt's letter of November 6, 1905:

It is hoped that before long private enterprise will take up the matter of erecting silk-reeling plants, and thus create a permanent market for the cocoons. In the meantime, so long as Congress appropriates for the purpose, we will buy cocoons at from 90 cents to \$1.15 per pound, at point of shipment, *for thoroughly dried cocoons*. Shipments weighing less than 4 pounds may be sent by mail, and for this purpose a Government frank will be provided on application, thus putting the shipper to no expense for transportation charges. Small lots of cocoons weighing something over 4 pounds may be divided into several shipments, each package being under a separate frank. Absolutely no cocoons must be sent by mail unless choked and dried. This is important, as otherwise there is liability of injury to other mail matter en route. Shipping by express has been found too expensive, and its use is now discouraged. Large shipments should all go by freight, *charges collect*. In no case where transportation is *prepaid* can the charges be refunded by this Bureau, neither will shipments by express be credited with expressage under any condition. We are operating a reeling plant at this office in order to convert cocoons into marketable raw silk.

From the above it is seen that persons producing even a small amount of cocoons can dispose of them at a price above the current European price *at point of shipment*. Anyone interested in the growing of silkworms should apply to the Secretary of Agriculture, Washington, D. C., for the Circular of Information in Regard to the Work in Silk Culture, and for Farmers' Bulletin No. 165, Culture of the Silkworm.

RESULTS OF EXPERIMENTS IN 1906.

On March 28, 1906, 1 ounce of eggs of the Oro race, a Chinese variety of silkworms, was received from the Bureau of Entomology, per the steamship *Alameda*. These eggs were forwarded from Washington, D. C., to Mr. E. M. Ehrhorn, deputy State horticultural commissioner, San Francisco, by mail on March 7, 1906. They were placed by Mr. Ehrhorn in cold storage aboard the steamer on March 15, 1906. On arrival in Honolulu the eggs were taken directly from cold storage aboard the steamer to the ice house of a meat company (temperature 42° F.). They were not exposed at once to hatch, since the mulberry trees had not at that time started to put out their new growth of leaves. This was unusual, but explained by the fact that there had been a drought of several months in length that had forced the trees into a semidormant state. On April 2 the eggs were inspected and the box found to contain many dead newly hatched worms. The writer could account for this state of affairs only upon the presumption that the development must have taken place en route from Washington to San Francisco, since the temperature on the steamer did not at any time exceed 40° F. The eggs were removed from the ice house at once and placed in an ice box at a temperature ranging between 50° and 60° . April 3 the eggs were exposed in the building used for the breeding purposes at a temperature ranging from 70° to 86° and the hatching began at once. Because of the shortage of the food supply only one-half of the eggs were retained for the experiment and the remaining half distributed to various parties who had from time to time requested eggs for breeding from an interest in the natural-history side. The hatching was very slow, and at the end of the fifth day, or on the morning of April 8, the remaining unhatched eggs, consisting of fully two-thirds of the half ounce, were thrown away. Despite the slow hatching the development was very regular, as shown by the following table. The date of hatching implies the worms hatched during twenty-four hours; for example, the hatching recorded on April 3 consists of the worms developing between 7 a. m. April 3 and 7 a. m. April 4.

Table showing hatching and development.

Date of hatching.	Molting periods.				Date of spinning.	Total life period (days).
	First.	Second.	Third.	Fourth.		
April 3.....	Apr. 10	Apr. 14	Apr. 19	Apr. 26	May 3	30
April 4.....	Apr. 11	Apr. 15	Apr. 20	Apr. 27	May 5	31
April 5.....	Apr. 12	Apr. 16	Apr. 22	Apr. 28	May 6	31
April 6.....	Apr. 13	Apr. 17	Apr. 23	Apr. 29	May 7	31
April 7.....	Apr. 14	Apr. 18	Apr. 24	May 1	May 8	31

The feeding table is incomplete, since at the beginning of the fourth age some of the worms had to be thrown away because of the shortage of the food supply; that is, less than one-sixth of an ounce of eggs were carried through to the cocoon stage. The amount of leaves fed is rather large, but it must be borne in mind that from the start the leaves were old and at every feeding there remained quite an amount uneaten to be thrown away.

Time of feeding and food consumed by silkworms from less than one-sixth ounce of eggs.

Date.	Times fed per day.	Amount consumed in 24 hours.	Date.	Times fed per day.	Amount consumed in 24 hours.	Date.	Times fed per day.	Amount consumed in 24 hours.
		Lbs. Oz.			Lbs. Oz.			Lbs. Oz.
April 3.....	7	0 $\frac{1}{2}$	April 16.....	7	2 0	April 29.....	6	16 0
April 4.....	7	0 $2\frac{1}{2}$	April 17.....	7	2 8	April 30.....	6	16 0
April 5.....	7	0 7	April 18.....	7	3 1	May 1.....	5	20 0
April 6.....	7	0 $8\frac{3}{4}$	April 19.....	6	3 0	May 2.....	5	22 0
April 7.....	7	0 12	April 20.....	6	4 0	May 3.....	5	25 0
April 8.....	7	0 12	April 21.....	6	5 0	May 4.....	5	31 0
April 9.....	7	1 0	April 22.....	6	6 0	May 5.....	5	35 0
April 10.....	7	1 0	April 23.....	6	6 0	May 6.....	5	20 0
April 11.....	7	1 0	April 24.....	6	7 6	May 7.....	5	18 0
April 12.....	7	1 8	April 25.....	6	10 0	May 8.....	5	10 0
April 13.....	7	1 8	April 26.....	6	10 0	May 9.....	5	5 0
April 14.....	7	1 8	April 27.....	6	13 0			
April 15.....	7	2 0	April 28.....	6	12 0	Total.....		314 $\frac{1}{4}$

The temperature ranged from 86° maximum to 65° minimum, with a mean maximum of 82.32° and a mean minimum of 67.62°; also during the above time the sky averaged part cloudy, with twelve clear days.

REPORT ON ORO COCOONS.

Under date of June 26, 1906, the following report was received from the Bureau of Entomology, United States Department of Agriculture:

DEAR MR. VAN DINE: Referring to my letter to you of the 22d instant, I beg to state that Mr. Gilliss reports as follows on your cocoons:

It is thought that the Oro Chinese race as a basis for crossing with other races may produce a cocoon particularly adapted to Hawaii. While the cocoons sent by you are somewhat undersized, they are of a very good quality, indeed, and contain a fair amount of silk. Of course, owing to adverse circumstances under which your worms were raised, it is hardly possible to consider this rearing as a fair test. We find it almost impossible to furnish you with silkworm eggs in good condition, owing to the length of journey and varying temperatures to which the eggs are necessarily

subjected en route. It is thought that you should be able to obtain eggs in better condition by shipping directly from the sericulture establishments of Japan and China. We are glad to know that the eggs furnished by us have proved to be healthy. The hatching of a certain proportion of the larvæ en route is a matter we can not control, as the journey between Washington and San Francisco must be performed without the use of cold storage.

The photographs are very interesting to us. We note that you use swinging shelves, presumably to guard against mice, ants, or other vermin, and we consider this an excellent idea. I might suggest, however, that, instead of the close-bottomed box used, it might be better to use something which would tend to ventilate the bed whereon the worms are being reared. Especially is this true during a moist, warm spell of weather, when the leaves tend to ferment and mold. Much attention has been paid by us to this point during the last season.

While we can not supply you with the number of mulberry trees which you would require in the carrying on of your work, we may be able next fall to send you several thousand seedlings of the best white mulberry if you wish.

Tests will be made within a short time regarding the length and strength of the fiber of your cocoons, and we will then take pleasure in advising you of results.

Yours, very truly,

F. H. CHITTENDEN,
Acting Chief of Bureau.

Mr. D. L. VAN DINE,

Hawaii Experiment Station, Honolulu, Hawaii.

BEEKEEPING.

The investigations relating to apiculture in Hawaii have been continued along the lines detailed in the project of this station on the subject. Two queens representing the Cyprio-Carniolan and Cyprio-Caucasian crosses, respectively, were received from the Bureau of Entomology and introduced in the apiary of a company on the island of Oahu. While a definite opinion can not be given at this time on the value of these bees as compared with the bees already established here, it can be said that they are at least as vigorous and industrious as our best Italians. Further introductions of desirable races and crosses are planned in cooperation with the Office of Apiculture, Bureau of Entomology.

Hawaii is particularly fortunate in that neither European nor American foul brood—serious diseases in most beekeeping sections of other countries—have not as yet gained a foothold in our apiaries. Suitable legislative action will be recommended to the next Territorial legislature to prevent, if possible, the introduction of these diseases or to deal with them should they unfortunately become established. As to enemies, none of serious consequence have been observed. Both the diseases and the enemies of bees will be carefully worked out and considered in a forthcoming bulletin on the industry.

The source and chemical characteristics of Hawaiian honeys have been little understood up to this time. This phase of the project has and will continue for some time to take up the greater part of the time

devoted to this part of the entomological investigations of the station. Up to the close of this fiscal year thirty-three samples of honey have been collected of which the source has been determined. These samples have been handed to the chemist of the station for analysis. The writer estimates that fully twice this number must be worked out before the completion of the survey of the sources of Hawaiian honey. In this connection, the question of introducing desirable bee plants for pasturage will receive attention.

The writer has been successful in forming a temporary organization of the beekeepers for the purpose of effecting a permanent association whose object will be the development of apiculture in Hawaii.

MOSQUITO CONTROL WORK.

Work along the line of this project has been confined almost entirely to the breeding and distribution of the top-minnows introduced from Texas during the early part of this fiscal year. To briefly summarize: The question of introducing special mosquito-eating fish to feed on the larvæ of mosquitoes in such collections of water as taro patches, rice fields, irrigation ditches, reservoirs, seacoast swamps, etc., was taken up with Dr. David Starr Jordan by the writer in the early part of 1903. Doctor Jordan recommended the top-minnows found in the Mississippi Valley, Florida, the Gulf States, and Mexico. The cost of the undertaking prevented anything from being done until a visit of Doctor Jordan to the islands made a personal interview on the subject possible. Doctor Jordan offered to send an expert from Stanford University to collect the fish and import them, providing the Territory would pay the expenses of the undertaking. During the session of the legislature in 1904 the matter was presented to the governor and received his indorsement, with the result that an item of \$1,500 for "Expenses, importation of fish for the destruction of mosquitoes," was appropriated. The legislature placed the item in the regular bill of expenses of the Territorial board of health, and accordingly that body had the disbursement of the money. Doctor Jordan selected Mr. Alvin Seale to undertake the work, and the writer procured the privilege of using a portion of a rice field on the country estate of Hon. S. M. Damon, at Moanalua for a breeding place, and therein prepared the breeding ponds to receive the fish.

The following report from Mr. Seale gives the method employed in collecting the fish and transporting them to the islands:

HONOLULU, HAWAII, *September 23, 1905.*

MR. D. L. VAN DINE,

Entomologist, U. S. Experiment Station, Honolulu, Hawaii.

DEAR SIR: In accordance with the following letter to yourself from Dr. David Starr Jordan I was chosen to attempt the introduction of "top-minnows," or

"killifish," into the Hawaiian Islands, for the purpose of destroying the larvæ of mosquitoes:

LELAND STANFORD JUNIOR UNIVERSITY,
OFFICE OF THE PRESIDENT,
Stanford University, Cal., April 18, 1905.

MR. D. L. VAN DINE,

United States Experiment Station, Honolulu, Hawaii.

DEAR SIR: The best place to collect the fishes which you want would doubtless be in Louisiana. It would probably take no longer time to bring them from there than from any other places nearer. Perhaps an equally good place would be Tampico, on the edge of Mexico. You understand that this would necessarily be an experiment. These little fishes feed freely on mosquitoes. Some live in brackish water, some in fresh water, and all of them are very hardy; but no one has ever tried to transplant any of them, and the whole thing might turn out, for some reason or other, to be a failure. Especially one would need to experiment on feeding the little fishes during their transportation. The genera which I would recommend are *Mollienesia*, *Adinia*, *Gambusia*, and *Fundulus*. Some of these are viviparous; others lay eggs. Whoever undertakes this should give a good deal of attention to the question of feeding the little fishes, and for this purpose, perhaps, a tank breeding mosquitoes would be as good as anything. The best time to undertake it would be about the 1st of June. I will select some one as soon as I hear from you.

Very truly, yours,

DAVID S. JORDAN.

On receipt of yours of July 11, 1905, with the advance of \$500 of the Territorial appropriation covering the expenses of this undertaking, I started from Stanford University to the Southern United States. It was my intention to secure the top-minnows at or near New Orleans, but the rigid quarantine in operation in Louisiana prevented my carrying out this plan. Seabrook, near Galveston, Tex., was then selected as the next place most available. At Seabrook I found the family of top-minnows, *Pœciliidæ*, in large numbers. They were swarming in all the stagnant waters at sea level as well as in various ditches, ponds, and standing pools. Mosquitoes are very plentiful in and about Seabrook, but after a study of the situation I am convinced that their source is not the bodies of water containing these fish but rather temporary and artificial breeding places, such as closed pools, tubs, tin cans, and other refuse which are not accessible to these fish.

As per his letter to you, Doctor Jordan recommended the following genera: *Mollienesia*, *Adinia*, *Gambusia*, and *Fundulus*. These are all members of the single family *Pœciliidæ*, or top-minnows. I first made a careful examination of a number of the stomachs freshly taken from members of the above genera. The stomach contents was found to consist largely of larvæ of various insects, including those of mosquitoes, egg masses of mosquitoes, minute crustaceæ, and some vegetation. The results showed that *Gambusia* were the best insect feeders. Of 100 stomachs of this genus examined, all contained many insect larvæ and eggs, among which I noticed especially numerous egg masses of the mosquito. However, *Mollienesia*, *Fundulus*, and *Gambusia* differed slightly in regard to their capacity for the various insect larvæ, and the difference was probably due to the different food localities. The temperature of the water in and about Seabrook in which these fish were found ranged from 74 to 87°.

It now remained to determine under what conditions the fishes could be most successfully transported to Hawaii. Six ordinary 10-gallon milk cans were prepared by puncturing the covers with numerous holes and placing the cans in bran sacks, the intervening space being tightly packed with Spanish moss. This served to keep the water at an even temperature. Two hundred fish were placed in each can. The

following morning so many were dead that it was evident the cans were overcrowded, and I reduced the number to 100.

Experiments were conducted as follows:

Can No. 1: Allowed to stand undisturbed. Water unchanged and unaerated. Temperature normal. The first morning 6 fish were dead. The second day 2 died. The third day the fish were perfectly lively and were taking food freely. The fifth day 5 died, and by the eighth 20 had died. The experiment was not carried further.

Can No. 2: Water changed once each day. Temperature normal (ranged from 74 to 78°). During the first three days there were 4 deaths. The eighth day 2 died. After this time there were no more deaths. Fish fed freely on mosquito larvæ and prepared fish food.

Can No. 3: Water changed twice each day. Temperature normal. Three deaths the first night. After this time there were no more deaths. Fish fed freely on mosquito larvæ and prepared fish food.

Can No. 4: Water changed every two days. Temperature normal. Five deaths the first three days, after which no fish died. Fish fed freely, keeping constantly at top of the water.

Can No. 5: Water slowly and very gradually reduced in temperature to 40°. Fish would not feed at the end of six days. During this time 18 had died. Experiment discontinued.

Can No. 6: Water reduced slowly to freezing point, then can packed in ice. At the end of six days all but 3 of the fish were dead. Experiment discontinued.

The above experiments demonstrated that the fish should be transported in water at the normal temperature and gave the necessary information in regard to the frequency of changing the water.

The three most abundant species, *Gambusia affinis*, *Fundulus grandis*, and *Mollienesia latipinna*, were collected and approximately 75 placed in each can. On September 4, 1905, I left Seabrook, Tex., on the long journey to Honolulu. A 20-gallon tin tank was taken along as a supply reservoir.

The following routine work was observed during the entire trip: At 8 a. m. the fishes were fed sparingly on prepared fish food, finely ground liver, or hard boiled eggs; at 9.30 half the water in each can was siphoned off from the bottom, thus cleaning out the cans and removing all uneaten food and excrement, and an equal amount of fresh water added; at noon the cans were all aerated by means of a large bicycle pump, a sponge being tied over the end of the hose to separate the air into fine particles; at 4 p. m. 2 gallons of water was siphoned off from the bottom and 2 gallons of fresh water put in; just before retiring the cans were again aerated by means of the air pump.

At each place en route where the water was changed it was first tested by placing two fish in a bucket containing the new water at the proper temperature. At El Paso, Tex., only, did the water kill the fish thus treated. After ten minutes the two fish were dead, probably due to the alkali the water contained. The water at Los Angeles was good, as also the San Francisco water, which was used from the latter place to Honolulu, an abundant supply being carried on the steamer. The water used from El Paso to Los Angeles was taken from the supply tank, filled at San Antonio, Tex.

Twelve fish died between Galveston and San Francisco, and only 15 between San Francisco and Honolulu. The fish were landed in Honolulu from the steamship *Alameda* on September 15, 1905, the trip from Texas occupying twelve days and 27 of the approximate 450 fish were lost.

The fish were in fine condition on arrival and, as prearranged by yourself, were placed in the breeding ponds prepared for them. The temperature of the water about Honolulu is almost identical with that where the fish were collected, and the

appearance of the fish at this writing indicates that they should thrive on the islands. The fish should be confined in the present breeding ponds, where they can be prevented from going out to sea or falling prey to other fish until their increased numbers permit general distribution to other localities in the group.

Very truly, yours,

ALVIN SEALE,
Assistant, U. S. Fish Commission.

The fish were divided into four lots and planted in as many places on the island of Oahu. In three places they were given their freedom under conditions distinctly different, and in the fourth place they were confined, namely, in the breeding ponds at Moanalua. The multiplication of these fish has been very rapid. Many hundreds have been distributed from the breeding ponds to various localities under varying conditions for observational purposes. The conditions under which they best thrive and the places best suited for them have been determined as a guide for their establishment throughout the islands. It is only a question of a few years when the shallow waters of the group, embracing the larger number of the natural collections of water where mosquitoes breed, will be teeming with these hardy, effective enemies of the mosquito larvæ. One point in this connection must be strongly emphasized—that is, that relief in towns, cities, and closely settled communities is dependent upon direct, active measures of control, since, in the main, the source of mosquitoes infesting closely settled districts is artificial collections of water, such as tubs, tanks, cesspools, discarded tins and bottles, gutters, water traps, and small ponds and ditches of a temporary character, or any collection of water not accessible to these fish. Relief implies general organized inspection and remedial work.

As stated in the 1905 report of the entomologist, organized effort to rid the islands of mosquitoes has ceased. This was due to the failure of the last legislature to provide the necessary funds to carry out the plans promulgated by the citizens' mosquito committee of Honolulu. The Territorial board of health, relying on money from private sources, has carried on control work in Honolulu and other districts of the islands, notably Hilo, as actively as the money available for the purpose would permit.

A PARTIAL LIST OF THE INJURIOUS INSECTS OF HAWAII, PART 3.

(Continued from Office of Experiment Stations Bulletin No. 170, 1906.)

SUGAR CANE.

The sugar-cane aphid (*Aphis sacchari*). Observed by Koebele in the cane fields of the islands of Oahu, Maui, and Kauai in 1896. At times appears in destructive numbers in certain localities, but not generally so. The ladybird beetle (*Coccinella repanda*) is a very

important enemy of this species. The writer is indebted to Mr. G. W. Kirkaldy for the determination of the sugar-cane aphid.

A longhorned grasshopper (*Xiphidium varipenne*). This species eats to some extent the leaves of cane, doing no serious damage. Mr. Otto Swezey has clearly pointed out during the year the remarkable fact that this species devours the sugar-cane leaf-hopper in sufficient numbers to consider the grasshopper of benefit in the cane fields. Injurious to the flowers of rice.

RICE.

Mole cricket (*Gryllotalpa africana*). Frequents wet places, feeding on the root system beneath the surface of the ground. Is injurious also to taro and sugar cane.

A longhorned grasshopper (*Xiphidium varipenne*). Feeds to slight extent on the margin of the leaves of rice, but the more serious damage to the crop is in gnawing through the glumes to obtain the pollen, on which it feeds extensively during the flowering season.

A shorthorned grasshopper (*Oxya velox*). Feeds to some extent on the leaves of rice.

The rice weevil (*Calandra oryzae*). A very common pest of stored products generally in Hawaii. The species is reported to infest the grain in the field before harvesting. This insect is very destructive to stored corn in the Kula district, island of Maui. Occurs in various foodstuffs aside from rice, especially flour, meal, breakfast foods, etc.

The rust-red flour beetle (*Tribolium ferrugineum*). Infests flour, meal, and rice. Taken also during the year in large numbers from fish guano and bone meal fertilizers.

The cadelle (*Tenebroides mauritanicus*). Taken in large numbers last year from bone meal and fish guano fertilizers. Reported as infesting stored rice.

MULBERRY.

The following scale insects infest the mulberry in Hawaii: *Pseudococcus nipæ*, *Pseudococcus filamentosus*, and *Saissetia* sp.

CEARA RUBBER.

A scale insect (*Saissetia nigra*) and a mealy bug (*Pseudococcus* sp.) were collected from Ceara rubber trees on the island of Kauai.

CITRUS TREES.

The orange aphid (*Myzus citricidus*). Very abundant and especially destructive to young growth. The species was recently described as new by Mr. G. W. Kirkaldy.

SCALE INSECTS, COCCIDÆ:

Chrysomphalus aonidum, collected during the year from orange. Found also on Allamanda and palms (*Pritchardia* spp.).

Pulvinaria psidii, on lime.

Pseudococcus filamentosus, at times very abundant. Especially injurious to young growth. The ladybird beetle (*Cryptolæmus montrouzieri*) is an important enemy of this scale.

Coccus viridis. Specimens of this scale were received from Mr. Jacob Kotinsky, collected from the "Giant lemon" at Honaunau, Kona district, island of Hawaii.

MANGO.

An undetermined lepidopterous larva was observed during the year destructive to the flowers of the mango and injuring partly developed fruit by feeding on the epidermis of mangoes in close contact in the cluster, between which the insect was hidden.

SCALE INSECTS, COCCIDÆ.

The mango scale (*Coccus mangiferæ*).

The Florida red-scale (*Chrysomphalus aonidum*).

Coccus longulus.

BANANA.

The scale insect (*Saissetia nigra*) was collected from the fruit and leaves of the banana during the year.

GRAPE.

The Japanese beetle (*Adoretus umbrosus tenuimaculatus*).

Fuller's rose beetle (*Aramigus fulleri*).

Lepidopterous larva (undetermined) observed by Mr. Jared G. Smith at Makawao, island of Maui, feeding on the stems of undeveloped fruit, causing the same to drop from the cluster.

SCALE INSECTS, COCCIDÆ.

The avocado mealy-bug (*Pseudococcus nipæ*).

Pseudococcus filamentosus.

MISCELLANEOUS.

The bean weevil (*Bruchus obtectus*) was taken from the seed pods of Klu (*Acacia farnesiana*).

The scale *Phenacaspis eugenixæ* is very common on oleander.

ACCESSIONS TO ENTOMOLOGICAL LIBRARY RELATING TO HAWAIIAN ENTOMOLOGY.

[This list is supplemental to the bibliography of Hawaiian entomology in the Report of the Entomologist for 1905 (Office of Experiment Stations Bul. 170). In the latter the references in the station library are marked with an asterisk (*).]

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REPORT OF THE HORTICULTURIST.

By J. E. HIGGINS.

CITRUS FRUITS.

The quality of the imported citrus fruits is in striking contrast with the excellency of those grown here and which may be picked from the trees in some part of the islands almost every day in the year. It is without exaggeration to say that by multiplying some of the Hawaiian seedling oranges the season could be extended to include almost the whole year in most localities. Lemons in several varieties, limes unsurpassed anywhere, and seedling pomelos that compare favorably in flavor with budded fruit are to be found in the gardens of Honolulu and other parts of Hawaii. To assist and encourage the further cultivation of these fruits the station published in the early part of the year Bulletin No. 9, "Citrus Fruits in Hawaii," which contains cultural instructions relating to soils, propagation by seeds, budding and grafting, irrigation, fertilizing, pruning, etc. Since the publication of the bulletin some interesting forms have been observed which are not there recorded. An orange has been noted which has a decided tendency toward the navel type and lacks nothing in flavor.

The citrus nursery at the station contains stocks of several species which are ready for budding.

MANGOES.

Bulletin No. 12, "The Mango in Hawaii," has also been published during the year and contains cultural instructions, methods of propagation, description of a large number of varieties, and notes on insects and diseases. The mango is destined to become one of the important tropical fruits of the American markets. That it can be shipped in cold storage has already been demonstrated, and the West Indies will probably supply the eastern markets in the near future. Hawaii should supply the Pacific slope with mangoes and even send some as far east as Chicago.

There is but one serious obstacle which may hinder this Territory from building up a large and important mango industry. The presence of the mango weevil (*Cryptorhynchus mangiferæ*) in Hawaii will be a serious hindrance to the progress of the industry so long as its ravages remain unchecked. All fruit which is under the suspicion of containing this insect will most certainly be quarantined. It is the important duty of the Territory in its own interests to take most stringent measures to control and destroy this insect. It is a duty also to the whole American mainland, since the insect is one that is likely to be introduced in hand baggage, or even in pockets, in spite of the most rigid inspection. A few thousand dollars spent now in efforts to stamp out the pest would mean a saving of millions in the future.

This station is making a collection of trees of all the finest varieties available and will propagate them on seedling stock.

DISTRIBUTION OF BLUEFIELDS BANANAS.

The Bluefields bananas which were introduced in cooperation with the Territorial board of agriculture and forestry have been cared for and multiplied sufficiently to warrant a general distribution throughout the island group. Over 500 suckers and large corms have been distributed, which would probably be equivalent to fully 1,000 suckers. These have been placed in lots of from 2 or 3 to 50, the size of the lot being determined by the locality and the facilities offered for cultivation. The distribution has been made with the understanding that those who have received the plants will care for the same, noting their growth and production and reporting from time to time. It has further been agreed that the Government shall receive from each grower a number of plants equal to that given if at any time in the future such should be needed for a further distribution. This variety of bananas, as has been stated in previous reports, was introduced because of certain advantages which it holds as a commercial banana. It is more easily shipped and is the variety which is best known in the American markets.

THE ROSELLE.

Among the plants which have been cultivated in the experimental plats during the year is the roselle (*Hibiscus sabdariffa*). The fleshy calyx of this fruit and the seed pod while young and tender are used in the manufacture of very excellent jam and jelly. The experiments conducted show the plant to be well adapted to local conditions. It produces a heavy yield of fruit per acre, amounting to 6,000 or 7,000 pounds under average conditions. The plant will tolerate a reasonable amount of dry weather, but responds freely to the application of water and produces more heavily. The seed is sown about March and the plants reset in the field when about 6 or 8 inches high, at distances about 4 by 6 feet if irrigation is to be practiced or if rainfall is abundant. In dry localities 4 feet by 4 feet will be sufficient. A new crop of larger area has been planted to continue the experiments through the coming year.

SYSTEMATIZING OF RECORDS.

Photographic records.—The photographs of the horticultural work have been indexed so as to make them readily available. All negatives have been filed in drawers in an index case and have been numbered consecutively in different series, determined by the size of the negative. One print from each negative has been mounted on especially prepared sheets and filed by subjects in a loose-leaf binder.

The number corresponding to that of the negative is placed under the print. By reference to this number the negative can be found immediately. The subject index is provided so that in a very few minutes it is possible to determine just what photographs are in the station file on any subject. This has already been of great convenience and should prove more valuable as the number of photographic records increases.

Records of plants.—The system followed in recording the planting of seeds, cuttings, tubers, etc., and of growing plants received from outside sources, has been simply that of consecutive numbering in an accession book where the date of planting is also recorded, the same number being placed upon labels in the pots, flats, or field. A card index arranged alphabetically has been made for convenient reference to plants in the propagating houses or fields. The cards contain the scientific name, the common name, if any, the variety, the date of planting, the sources from which received, the places where planted, and other important data.

The following is a list of some of the accessions which have been made during the year ending June 30, 1906:

Accessions by the horticultural department, 1906.

Scientific name.	Common name, or variety.	Remarks.
<i>Citrus aurantium sinensis</i>	Hawaiian summer orange	
<i>Passiflora quadrangularis</i>	Granadilla	
<i>Mangifera indica</i>	Mango	For stock in nursery.
<i>Manihot glaziovii</i>	Ceara rubber	Germination test.
<i>Mangifera indica</i>	Mango	Seeds of selected varieties.
Do	do	Experiments with position of placing seeds.
<i>Persea gratissima</i>	Avocado	Nursery stock.
<i>Nephelium litchi</i>	Litchi	Do.
<i>Ananas sativus</i>	Natal pineapple.....	S. P. I. 9634. ^a
<i>Thysanotena agrostis</i>	Ornamental grass	S. P. I. 14922.
<i>Coffea liberica</i>	Liberian coffee	
<i>Musa sapientum</i>	Banana Manzano	
Do	Banana Puano	
Do	Banana Morado Blanco	
Do	Banana Johnson	From Porto Rico Experiment Station.
Do	Banana Morado	
Do	Banana Datil	
Do	Banana Macho	
<i>Nephelium longana</i>	Longan.....	
<i>Coffea</i> sp.....	Harras coffee	S. P. I. 11354.
<i>Anona cherimolia</i>	Cherimoyer	S. P. I. 9466.
<i>Quebrachia lorentzii</i>.....	.....	S. P. I. 6345.
<i>Erythroxylon coca</i>.....	.....	S. P. I. 6447.
<i>Cissus</i> sp.....	.....	S. P. I. 7383.
<i>Harpephyllum caffrum</i>	Kafir plum	S. P. I. 9616.
<i>Mimosa afzallii</i>.....	.....	S. P. I. 3783.
<i>Erythrina canna</i>.....	.....	S. P. I. 3787.
<i>Tamarindus indicus</i>.....	.....	S. P. I. 3780.
<i>Ficus carica</i>	Caprifig	S. P. I. 6780.
<i>Carica quercifolia</i>.....	.....	S. P. I. 8960; produces the vege- table pepsin of commerce.
<i>Garcinia</i> sp.....	.....	S. P. I. 9569.
<i>Cesalpinia gilliesii</i>.....	.....	S. P. I. 8935.
<i>Maytenus boaria</i>.....	.....	S. P. I. 8921.
<i>Grabowskia glauca</i>.....	.....	S. P. I. 8956; hedge plant.
<i>Anacardium occidentale</i>	Cashew	S. P. I. 12809.
<i>Psidium</i> sp.....	Guava	S. P. I. 11726; a large red variety.
<i>Mangifera</i> sp.....	The Saigon mango	S. P. I. 11645.
<i>Psidium</i> sp.....	Guava	S. P. I. 13803; an Argentine guava.

^aSeed and Plant Introduction Number, U. S. Department of Agriculture.

Accessions by the horticultural department, 1906—Continued.

Scientific name.	Common name, or variety.	Remarks.
<i>Santalum album</i>	White sandalwood	
<i>Mimusops elengi</i>		
<i>Erythrina suberosa</i>		
<i>Bixa orellana</i>		
<i>Pentzia virgata</i>		A composite, valuable as fodder.
<i>Mangifera indica</i>	Douglas Bennett's Alphonse mango.	S. P. I. 8727.
Do	Totafari	S. P. I. 8732.
<i>Spondias lutea</i>		S. P. I. 9009.
<i>Musa</i> sp.	Banana	S. P. I. 13568.
<i>Palisota bartori</i>		
<i>Eriodendron anfractuosum</i>		S. P. I. 14813
<i>Strychnos nux vomica</i>		
<i>Musa sumatrana</i>	Ornamental banana	
<i>Musa rhodochlamys</i>	do	
<i>Musa superba</i>	do	
<i>Carica papaya pyriformis</i>	Papaya	
<i>Musa ornata rosea</i>	Ornamental banana	
<i>Musa religiosa</i>	do	
<i>Musa martinii</i>	do	
<i>Musa gillettii</i>	do	
<i>Acacia giraffe</i>		
<i>Acacia semperflorens</i>		
<i>Asparagus plumosus blamptedii</i>		
<i>Asparagus plumosus nanus</i>		
<i>Asparagus springeri</i>		
<i>Asparagus decumbens</i>		
<i>Hibiscus rosa-sinensis</i>	Punicens (?)	
<i>Bauhinia montana</i>		
<i>Bauhinia purpurea</i>		
<i>Bauhinia esculenta</i>		
<i>Ipomoea umbellata</i>	Morning-glory	
<i>Ipomoea setosa</i>	do	
<i>Kickxia elastica</i>	Silk rubber	
<i>Citrus decumana</i>		
<i>Psidium cattleianum</i>	Strawberry guava	
<i>Coffea arabica</i>	Coffee	From Cape Verde Islands.
<i>Gloxinia hybrida robusta</i>		
<i>Nicotiana glauca</i>		
<i>Monstera deliciosa</i>		S. P. I. 15673.
Do		From local plants.
<i>Brachychiton populneus</i>	Carryong tree	
<i>Diospiros ebenaster</i>	Sapote, negro wood	
<i>Ipomoea batatas</i>	Sweet potato	21 varieties.
<i>Persea indica</i>		S. P. I. 16133.
<i>Coffea zanguebariae</i>		S. P. I. 12897.
<i>Vanilla planifolia</i>	Vanilla	
<i>Ricinus lauricartensis</i>		
<i>Castilloa elastica</i>	Central American rubber tree	
<i>Canavalia</i> sp.		S. P. I. 17957.
<i>Bauhinia kurgii</i>		S. P. I. 17955.
<i>Eugenia punicifolia</i>		S. P. I. 17956.
<i>Anona muricata</i>	Soursop	
<i>Artocarpus incisa</i>	Breadfruit	
<i>Artocarpus integrifolia</i>	Jackfruit	
<i>Chrysophyllum cainito</i>	Star apple	
<i>Citrus medica limon</i>	Sicily lemon	
<i>Cucurbita lagenaria villosa</i>		
<i>Cucurbita</i> sp.		S. P. I. 15937.
<i>Agave rigida elongata</i>	Henequen	
<i>Crotalaria juncea</i>		
<i>Vitis</i> spp.	Grapes	About 100 varieties of wine and table grapes.

ORGANIC NITROGEN IN HAWAIIAN SOILS.

By E. C. SHOREY,^a *Chemist.*

INTRODUCTION.

The importance of the nitrogen problem in agriculture has never been more generally recognized than at the present time.

A recent writer on the subject has stated that the nitrogen in the air covering 5 acres of the earth's surface is equal to that contained in 1,000,000 tons of nitrate of soda, the amount consumed annually in Europe.^b

Briefly stated, the nitrogen problem is as follows: So far as known none of the higher plants constituting ordinary agricultural crops obtain their nitrogen in any other way than through the soil. The nitrogen of the soil has been at some time the free nitrogen of the air. The processes by which this free nitrogen has become fixed in the soil are not all definitely known. It is known, however, that they are slow. Of the elements taken from the soil by plants there is, as a rule, in the soil and the rocks from which soils are being formed an abundant supply of those of a mineral nature. Moreover, these elements after the growth and consumption of a crop find their way for the most part back to the soil. On the other hand, the nitrogen taken from the soil by growing plants is ultimately in large part returned to the air as free nitrogen.

We have, then, two cycles of an opposite nature. The mineral ingredients of rocks become part of the soil, are taken up by plants, and then by decay or consumption by man or animals are returned to the soil to begin the cycle again. With nitrogen we have the free nitrogen of the air becoming fixed in the soil by slow natural processes, then becoming a part of growing plants, and on the decay or consumption of these plants becoming again free nitrogen of the air.^c The nitrogen problem arises because under the conditions incident to civilization this cycle is not balanced. The growing of crops, the feeding of stock, and man return free nitrogen to the air faster than the processes of nature fix it in the soil again. The problem, then, is

^aTransferred to Bureau of Soils, U. S. Department of Agriculture, December 8, 1906.

^bP. A. Guye, Paper read before the Swiss Society of Natural Science, 1906.

^cThe statement given above of the relation of plants to the nitrogen of the atmosphere is intended to be most general in character. The cycles are seldom as simple as stated, and the contention made by T. Jamieson (Agr. Research Assoc. [Scot.] Rpt., 1905, pp. 81) that plants utilize the free nitrogen of the air through specialized hairs on the leaves is ignored as not being proven.

how to aid or supplant nature's processes and fix or render available for the growth of plants the free nitrogen of the air by artificial means.

There is no doubt that this problem will be solved. It has been attacked from several points by many workers, and along two lines progress has been made to the extent that the problem now is to reduce the cost of production.

There is, however, one phase of the nitrogen problem which has not received the attention it warrants. Many soils contain relatively large amounts of nitrogen. On many such soils containing nitrogen sufficient for many crops it has been found profitable to use nitrogenous fertilizers. This is usually explained by stating that the soil nitrogen is not available.

There are in Hawaii thousands of acres of which the soil contains 20 tons of nitrogen per acre-foot, and a pertinent question in this connection is, why apply nitrogenous fertilizers to such soils; or, to put the question in another form, why can not some of this nitrogen stored in the soil be made to perform the functions of the nitrogen applied in fertilizer, whatever these may be? To answer these and many other questions suggested by this condition, it is necessary to know something about the nitrogenous compounds in the soil. When, however, we face this question, we find that there is absolutely no definite knowledge regarding the chemical composition or constitution of these bodies.

With the belief that how to utilize the nitrogen already in the soil is an important phase of the nitrogen problem, and with the aim to add something to our knowledge of the chemical composition and constitution of the nitrogenous compounds in the soil the soil studies of which the present paper is the first part were undertaken.

NITROGEN IN HAWAIIAN SOILS.

Hawaiian soils differ from those of the American mainland in several respects. Maxwell^a has pointed out some of these, particularly the highly basic character of Hawaiian soils. Among the important points of difference is one which may be a difference of degree rather than of kind. This is the large amount of organic matter and nitrogen contained in them. Many analyses of Hawaiian soils, by several methods, have been made, but few have been published. Among the general statements regarding the average nitrogen content of Hawaiian soils which have been published the following are the most important. Eckart^b states the average nitrogen content of Hawaiian cane soils as follows: Oahu, 0.119 per cent; Maui, 0.222 per cent; Kauai, 0.246 per cent;

^a *Lavas and Soils of the Hawaiian Islands*, Honolulu, 1898.

^b *Hawaiian Sugar Planters' Sta., Div. Agr. and Chem. Bul.* 15, p. 7.

and Hawaii, 0.388 per cent. Maxwell^a states the average nitrogen content of upland and lowland cane soil to be upland, 0.456 per cent; lowland, 0.195 per cent. In a later publication the same writer^b gives the average nitrogen content of 48 samples of cane soil from districts on Hawaii as follows:

Average nitrogen content of Hawaiian soil.

District.	Number of samples.	Nitrogen.
		<i>Per cent.</i>
Kohala	19	0.515
Hamakua	14	.572
Hilo	6	.633
Do.	2	.840
Kau	7	.482

Hartmann has published analyses of 12 samples of soil from the plantation of the Onomea Sugar Company on Hawaii, showing a nitrogen content ranging from 0.56 per cent to 0.89 per cent.^c

Soils above the elevation at which cane is grown are, as a rule, still higher in nitrogen. This is particularly true of the upland soils of Hawaii. Maxwell^a states the average nitrogen content of the coffee lands in this section to be 1.237 per cent.

The writer has examined soils as to their nitrogen content, from the upper lands throughout the Territory, the amount ranging from 0.30 per cent to 2.20 per cent; and it is thought that a conservative estimate of the nitrogen content of the uplands in cultivation is somewhat as follows. The upland soils on the islands other than Hawaii contain from 0.3 per cent to 0.5 per cent nitrogen, the upper cane soils and those of the adjoining coffee lands on the windward side of Hawaii contain from 0.75 per cent to 1.25 per cent nitrogen, and limited areas on Hawaii contain as much as 2.2 per cent.

The organic matter in these soils as determined by loss on ignition is proportionately high, and the same is true of the humus as determined by the chemical methods at present in use.

As is usually the case with highly organic soils these are very retentive of moisture. Soils containing 10 to 12 per cent humus, which corresponds roughly to 0.75 per cent to 1.0 per cent nitrogen, generally contain when air dried 15 per cent to 20 per cent moisture. The determination of moisture in soils of this character, by loss in weight on drying at 100° C., has been checked in a number of cases by passing a current of dry air through the soil at 100° C. and then into a drying tube containing strong sulphuric acid. The moisture determined by increase of weight of the drying tube has agreed with the loss in

^a Lavas and Soils of the Hawaiian Islands, p. 67, Honolulu, 1898.

^b Hawaiian Sugar Planters' Sta., Div. Agr. and Chem. Bul. 2, p. 3.

^c Hawaiian Planters' Mo., 16 (1897), p. 171.

^d Lavas and Soils of the Hawaiian Islands, p. 67, Honolulu, 1898.

weight of the soil; the sulphuric acid was not colored and did not contain nitrogen, showing that the loss in weight is not organic matter.

While soils unusually high in nitrogen are very common in Hawaii, there are also some very low in this constituent; some containing as little as 0.05 per cent. These soils are found, for the most part, on the lowlands, especially on Oahu, and some cane lands of this character are the most productive in the Territory if not the most productive in the world. While the productiveness of these soils is no doubt in a large measure due to favorable conditions, such as temperature, texture of soil, absence of high winds, and abundant irrigation, no one who has followed their development can doubt that it is also due in no inconsiderable part to the use of fertilizers, especially the application of nitrate of soda.

The scientific investigation of Hawaiian soils has, up to the present time, been confined almost altogether to those devoted to the growth of cane, and as a result of the work of the experiment station of the Hawaiian Sugar Planters' Association fertilizers are now used almost universally on Hawaiian sugar plantations. Nitrogenous fertilizers constitute a considerable portion of those used. For the crop of 1903 Hawaiian planters used 6,000 tons of nitrate of soda and 2,500 tons of nitrogen in other forms.^a

Crawley^b says more is spent in Hawaii for nitrogenous fertilizers than for all others combined.

Most of the land in Hawaii available and suitable for crops such as coffee, tobacco, pineapples, etc., is above the cane level and relatively of high nitrogen content. Now, in view of the fact that planters on the lowland find it profitable to use large quantities of nitrogenous fertilizers, what is the proper course for the grower of other crops on the uplands, where thousands of tons of nitrogen are apparently locked up in the soil?^c

^aC. F. Eckart, Hawaiian Sugar Planters' Sta., Div. Agr. and Chem. Bul. 9, p. 62.

^bHawaiian Planters' Mo., 25 (1906), p. 222.

^cThe average weight of an acre of Hawaiian soil to the depth of 1 foot is 3,888,000 pounds. (J. T. Crawley, Hawaiian Planters' Mo., 21 (1902), p. 359.) Using this weight as the basis of calculation we have the following figures:

Nitrogen per acre-foot of Hawaiian soil.

Nitrogen soil.	Nitrogen per acre- foot.	Equivalent in nitrate of soda per acre-foot.
<i>Per cent.</i>	<i>Pounds.</i>	<i>Pounds.</i>
0.05	1,944	14,034
.10	3,888	28,068
.50	19,440	140,340
1.00	38,880	280,680
2.00	77,760	561,360

Or, assuming that the nitrogenous compounds in the soil contain the same amount of nitrogen as protein, we have for 1 per cent nitrogen in the soil 126 tons of nitrogenous compounds per acre-foot.

Viewed from the standpoint of the cane planter, this problem presents itself somewhat as follows: If on a soil containing 0.1 per cent or less nitrogen three or four times as much sugar is produced as on a soil containing 0.1 per cent to 1 per cent; and if in the first case large amounts of nitrogenous fertilizers have been found to be an important factor in producing the crop, may one not temporarily neglect the other factors and ask something about the nitrogen already in the soil in the latter case? Some of the questions which this view of the problem suggests are: (1) In what form does the nitrogen occur in these soils? (2) Can it be converted into nitrates; and if so, under what conditions? (3) Is any of it available in organic form or in any form other than nitrates? (4) Does it occur in any form injurious to plant life?

OUR KNOWLEDGE OF SOIL NITROGEN.

These questions at once suggest the more general one: How much do we know about the nitrogen in the soil? If an attempt is made to answer this question with regard to Hawaiian soils, we find that, despite the fact that there has been little or no investigation of the organic matter in these soils, our knowledge of the composition and constitution of the organic or nitrogenous bodies in them is just as extensive and accurate as that of these bodies in soils elsewhere. In other words, our knowledge of the composition and constitution of these bodies is of the most general nature and may be said to apply to all soils.

Our knowledge of the nitrogenous bodies may be stated shortly as follows: In most soils there is, under ordinary conditions, some nitrogen present as nitrates. This amount is always small and is a constantly fluctuating quantity. There is also in most soils a small amount of nitrogen present as ammonium compounds, and under certain conditions a small amount may be present as nitrites. The amount of nitrogen present as nitrates, ammonia, and nitrites probably seldom exceeds 5 per cent and more often is not 1 per cent of the total. The remainder is organic, and a portion of this is what is known as humus nitrogen.

The term humus as used by agricultural chemists is the name applied to the dark-colored organic matter extracted from the soil by alkaline solutions. The method at present in use for determining humus is essentially that of Grandeau,^a who applied the term "*matière noir*" to the extract.

In this extract certain acids—humic, ulmic, crenic, and apocrenic—have been said to exist, but, viewed in the light of modern organic chemistry, these compounds are wholly without standing. A number of chemists have given the percentage composition of these supposed acids, but no two agree. Nothing is known as to their constitution,

^a *Traité d'analyse des matières agricoles*, p. 148. Paris, 1877.

the presence of the carboxyl group essential to the constitution of an organic acid has never been demonstrated, and all the evidence is to the effect that they are not acids. The lack of standing of these compounds is concisely stated by Cameron^a as follows: "The existence itself of these acids has never been demonstrated. * * * No satisfactory description of the physical or chemical properties of these supposed acids, their salts, or characteristic derivatives, have been recorded." This statement can not be controverted, and yet in spite of this we find in nearly every treatise on soils from Mulder in 1840 to the present these acids are spoken of with the same assurance that one would speak of citric, tartaric, or any other organic acid the constitution and derivatives of which are well known. Even so recent a writer as Hilgard^b uses the names of these supposed acids in this way.

It has been customary for chemists to determine humus by extracting the soil with ammonia and to determine the humus nitrogen in a similar extract made with caustic soda, to obviate the difficulty of distinguishing between the nitrogen of the soil and that of the ammonia when it is used as a solvent. Rimbach^c has, however, shown that these two solvents do not extract the same amounts of nitrogen from the soil, the greater amount being extracted by caustic soda. This fact is one indication of the complex nature of the soil extract known as humus. The certainty of its complexity is emphasized when we consider that humus is the result of the decay of living tissues in the soil, and is simply a stage in the resolution of living matter into free nitrogen, carbonic acid, and ash ingredients, from which it was formed.

Soil humus, then, may be defined as a group of complex organic bodies containing nitrogen which can be extracted from the soil by dilute alkalis. Some of the bodies in this extract can be precipitated by dilute acids, which precipitate can be dissolved again by alkalis. Some of the bodies included in this group seem to be capable of entering into combination with mineral ingredients in the soil and others have the power of holding, in a form little soluble in water, both mineral and organic compounds which otherwise are freely soluble. In short, humus is a name for a group of bodies of which we know very little, and this meager knowledge is remarked in nearly every work on agriculture. For instance, King^d says: "The humus of soils so far as its chemical composition is concerned is not well understood." Storer^e says: "Little is known as yet as to the precise chemical composition of humus."

^a U. S. Dept. Agr., Bureau of Soils Bul. 30, p. 39.

^b Soils, pp. 126, 322. New York and London, 1906.

^c Journ. Amer. Chem. Soc., 22 (1900), p. 695; California Sta. Rpt. 1899-1901, pt. 1, p. 43.

^d The Soil, p. 94. New York and London, 1897.

^e Agriculture In Some of its Relations with Chemistry, Vol. II, p. 187. New York, 1897, 7th ed.



FIG. 1.—VEGETATION ON VIRGIN SOIL, 1,600 FEET ELEVATION, HAWAII.

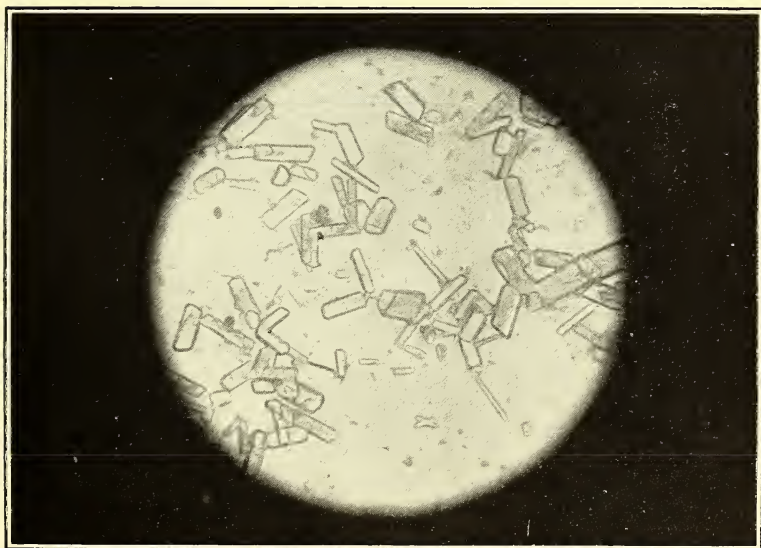


FIG. 2.—PICOLIN CARBOXYLIC ACID FROM POHAKEA SOIL.

There is always a considerable portion of the organic soil nitrogen that is not extracted by alkaline solutions, or is not humus nitrogen as the term is ordinarily used. Of this portion, which often amounts to 50 per cent of the total, still less is known than of humus nitrogen. This group of organic bodies has been given no group name and has been practically ignored, except that it has been considered unavailable in distinction to humus nitrogen as available.

OBJECTS OF STUDY OF SOIL NITROGEN.

The objects in mind in undertaking a study of the nitrogenous compounds in Hawaiian soils were—

(1) To determine more definitely than is now known the chemical composition and constitution of the group of bodies known as humus.

(2) To determine the identity and constitution of organic nitrogenous bodies other than humus.

(3) To determine to what extent the bodies studied under (1) and (2) can be nitrified and under what conditions.

(4) To determine whether organic nitrogenous bodies in the soil can be directly assimilated by plants.

(5) To determine whether any organic nitrogenous bodies in the soil are poisonous or injurious to plants.

SPECIAL SOIL STUDIED.

In attempting to carry out the work so planned it was decided to confine the preliminary work to one soil, typical of a large area fairly high in nitrogen. For this purpose soil was chosen from Pohakea, Hawaii, at an elevation of 1,600 feet (Pl. III, fig. 1). The analysis of this soil by official methods gave the following figures:

Mechanical analysis.

[Soil passed 2-millimeter sieve and analysis calculated to soil free of water and organic matter.]

	Per cent.
Fine gravel, 1-2 mm.....	25.772
Coarse sand, 1-0.5 mm.....	17.697
Medium sand, 0.5-0.25 mm.....	10.498
Fine sand, 0.25-0.1 mm.....	21.856
Very fine sand, 0.1-0.05 mm.....	13.018
Silt, 0.05-0.005 mm.....	9.129
Clay, 0.005-0.0001 mm.....	2.030

Chemical analysis.

[Soil passed 0.5 millimeter sieve.]

	Per cent.
Moisture.....	19.540
Organic matter and combined water.....	28.360
Insoluble.....	19.320
Iron and alumina.....	28.797
Lime.....	3.00

	Per cent.
Magnesia	0.631
Sulphuric acid .....	.343
Phosphoric acid .....	.703
Potash .....	.077
Nitrogen .....	.728
Humus	12.470
Humus nitrogen .....	.560

Larger samples taken at a later date showed some variation from these figures, the nitrogen varying from 0.700 per cent to 1.010 per cent.

The location of this soil is in the coffee district on the windward side of the island of Hawaii. The samples were taken from land which had been cleared a short time, but had borne no crop. Land in this section before clearing is covered with a tangled growth of ferns, tree ferns, and forest trees, chiefly ohia (*Eugenia malaccensis*), and the soil has been formed in place by the decay of this luxuriant vegetation mixed with the disintegrated lava which forms the basis of all Hawaiian soils. This district is on the rainy side of the island, but is subject at times to severe drought. A record of the rainfall for the last ten years at 1,450 feet elevation a few miles from this location shows the following figures: Highest annual rainfall, 275.46 inches in 1902; lowest, 52.62 inches in 1897; highest monthly rainfall, 93.39 inches in March, 1902; lowest, 0.09 inch in December, 1899. A period of drought occurred in 1901, the rainfall being, May, 0.46; June, 0.21; July, 1.07; August, 0.26, and September, 0.70 inches. In the following year the rainfall for the same months was, May, 29.88; June, 12.65; July, 2.48; August, 32.62, and September, 8.06 inches.

The temperature in this district, as throughout the Territory, is fairly equable, seldom being as low as 55° F. or higher than 85° F. The formation of a soil rich in nitrogen and organic matter under such conditions is somewhat at variance with the generally accepted ideas regarding such soils. Theoretically, one might expect, with a moderate to high temperature, heavy rainfall alternating with dry weather, and a porous, easily drained soil, that the organic matter resulting from vegetable decay would rapidly disappear or be resolved into its elements as the final stage of such decay. That such has not been the case indicates some organic form very resistant to further action by the agents active in the soil. Whether this resistant form is one depending on organic constitution, one of combination with the mineral ingredients of the soil, or one of absorption is of course not known.

GENERAL PROPERTIES OF THE SOIL.

In addition to the general properties already noted this soil presents the following general characteristics:

Solubility.—The behavior of the nitrogenous compounds with regard to a number of solvents is shown by the following figures, the

nitrogen dissolved being stated as per cent of the soil. The soil was that which passed a 1-millimeter sieve, and the total nitrogen was 0.862 per cent.

Solubility of the nitrogen compounds of the soil.

Solvent.	Nitrogen in solution, calculated to original soil.
	<i>Per cent.</i>
Distilled water, 30° C. 1 hour.....	0.005
Distilled water, 100° C. 1 hour.....	.022
Distilled water, 125° C. 3 hours.....	.050
95 per cent alcohol, 30° C.....	None.
12 per cent hydrochloric acid, 30° C. 1 hour.....	.002
12 per cent hydrochloric acid, 100° C. 7 hours.....	.623
5 per cent caustic potash, 100° C. 1 hour.....	.728
Acid pepsin, 40° C. 1 hour.....	.076
Cuprichydrate, 100° C.....	.011
2 per cent permanganate of potash, 100° C. $\frac{1}{2}$ hour.....	.516

From these figures and other observations which have been made, the conclusion is warranted that the nitrogenous bodies in the soil are extremely insoluble in common solvents at the ordinary temperature, with the exception of dilute alkalis, as in the determination of humus. Acids and oxidizing agents at boiling temperature render a large portion soluble, this solubility being evidently due to change in constitution.

Ammonia.—The soil on distillation with excess of magnesia gave nitrogen as ammonia 0.007. Using milk of lime instead of magnesia and distilling in a current of steam, the nitrogen obtained as ammonia was 0.035 and on distillation with direct heat 0.053. Distillation with 1.5 per cent caustic soda gave nitrogen as ammonia 0.154. It is seen from these figures that only a small portion of the nitrogen in the soil can be present as ammonium compounds, but a large amount is readily split off as ammonia by alkalis at an elevated temperature.

Dry or destructive distillation of the soil gives an alkaline distillate containing ammonia. The alkalinity of this distillate was found to be equivalent to nitrogen as ammonia 0.168, the total nitrogen in the distillate being 0.145. In addition to ammonia this distillate contains pyridin or some of its homologues, and a portion of the alkalinity is due to these bodies. This seems to indicate the presence of some pyridin ring compound in the soil.

DECOMPOSITION PRODUCTS.

Much of our rather meager knowledge of the complex protein molecule is due to the study of its decomposition products. When the protein molecule is dissociated, whether the means be chemical in the laboratory or the agency of ferments in decay, it splits along certain lines of cleavage and bodies are obtained which have been designated primary dissociation products. The establishment of the constitution

of these bodies has thrown some light on the constitution of the parent body. The reagent most commonly used in the laboratory in bringing about this dissociation has been boiling dilute acids. The literature of this subject is now quite voluminous and dates from 1818, when Proust^a discovered leucin in cheese. A good general account of the subject is given by Kossel and Kutscher.^b

With regard to the nitrogen in the soil, it is safe to assume that a large part, if not all, of it has been at some time a component part of the protein molecules in living plants. Whatever may have been the initial stage in the transfer of the free nitrogen of the air to the soil, the stages immediately preceding the final step have no doubt been living protein, dead protein, decaying protein. Such being the case, one might expect some parallel between the compounds resulting from the decay of plant compounds in the soil and the dissociation products obtained in the laboratory. In the soil, however, the study of the process of dissociation is complicated by several factors; the large amounts of mineral matter present may enter into combination with the organic bodies formed; certain organic bodies formed have an absorptive power for others; and, finally, while the process is going on these dissociation products are subject to loss through solution and leaching from the soil or subject to further complex changes by the numerous agents at work in the soil. We would expect, then, that the soil would contain plant residues not yet dissociated and such products of dissociation as had resisted leaching, some probably in combination with the mineral matter in the soil, others absorbed, and still others present as secondary products.

With this in mind a method of classifying the dissociation products of protein proposed by Osborne and Harris^c was applied to the soil. This method, which is a modification of that of Hausmann,^d is in short as follows:

Boiling the material with dilute acid, removing the excess of acid by evaporation, determination of the nitrogen present as ammonia by distilling with magnesia, determination of the nitrogen in the magnesia precipitate, precipitation of the basic nitrogen in the filtrate by phosphotungstic acid, and the determination of the nonbasic nitrogen by difference. In applying this method to soil 10 grams were boiled under a reflux condenser with 100 cubic centimeters, 12 per cent hydrochloric acid, usually for seven hours, and the insoluble residue boiled for the same time with 100 cubic centimeters sulphuric acid, the process as outlined being carried out with the two solutions separately, the removal of excess of acid by evaporation of course being applied to the hydrochloric-acid solution only.

^a Ann. Chim. et Phys., 10 (1819), p. 40.

^b Ztschr. Physiol. Chem., 31 (1900), p. 165.

^c Jour. Amer. Chem. Soc., 25 (1903), p. 323.

^d Ztschr. Physiol. Chem., 27 (1899), p. 95.

In treating the soil with boiling hydrochloric acid of this strength the amount of nitrogen rendered soluble was found to be increased very little on prolonging the boiling more than two hours. The difference between boiling two hours and fourteen was found to be 0.08 per cent nitrogen, the total amount in solution at the end of fourteen hours being 0.630 per cent. During the first hour of boiling there is much frothing, and if the operation is stopped at this stage a somewhat viscous solution is obtained very difficult to filter. This viscous character of the solution wholly disappears after two hours, and it is evident that the prolonged boiling brings about some change in constitution, and is not merely a separation of organic bodies from combination with the basic elements in the soil.

This method when applied to the soil gave the following figures:

Solubility and forms of nitrogen in acid solutions.

	HCl solution.	H ₂ SO ₄ solution.	Total.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Nitrogen in solution	0.623	0.112	0.735
Nitrogen as ammonia .....	.119	None.	.119
Nitrogen in MgO precipitate .....	.280	.105	.385
Basic nitrogen .....	.140	.005	.145
Nonbasic nitrogen .....	.084	.002	.086

Considering these dissociation products in detail, the following points should be noted. The whole of the ammonia is that obtained from the hydrochloric-acid solution. The ammonia already present in the soil was 0.007, leaving 0.112 split off by the action of boiling acid. Practically all investigators agree that ammonia is one of the primary dissociation products of boiling protein with acids.^a Determination of ammonia in this method by distilling with magnesia is open to the objection that ammonia may be formed as a secondary product; but neglecting the error due to this, which must be small in any case, we have the following conclusion warranted by the figures obtained. There is present in the soil 0.007 ammonia as the residue of previous dissociation through decay, and if subsequent dissociation in the soil should be of a similar character to that produced by acids in the laboratory there would finally result 0.112 ammonia. Just how far the two methods of dissociation are similar, and how much of the ammonia would remain fixed in the soil and how much lost by leaching or further chemical change, is of course unknown.

The nitrogen in the magnesia precipitate has been by most investigators designated "humin nitrogen." The term humin was first used by Berzelius^b instead of "ulmin and geine," which had been applied

^a O. Nasse, Arch. Physiol. [Pflüger], 6 (1872), p. 589; 7 (1873), p. 139; 8 (1874), p. 381. H. Hlasiwetz and J. Habermann, Liebig's Ann. Chem., 169 (1873), p. 150. A. Kossel and F. Kutscher, Ztschr. Physiol. Chem., 31 (1900), p. 165. E. Fischer, Ibid., 33 (1901), p. 151; 33 (1901), p. 177; 35 (1902), p. 70; 36 (1902), p. 462.

^b Poggendorff's Ann., 44 (1838), p. 375.

to the dark-colored constituents of vegetable mold. Mulder^a showed that brown or black substances of a similar nature were formed on boiling albumins with strong acids; and later other investigators showed that humin substances were formed in the same way from many other bodies, especially carbohydrates.^b

When the body acted on contains nitrogen the resulting humin substance also contains nitrogen, and the same is true for iron and sulphur. Schmiedeberg^c has shown that these humin substances present a great resemblance in properties and chemical composition to the dark pigment in hair and skin. These pigment substances are known as melanins, and he has proposed for the humin substances the name melanoidins. The humin substances or melanoidins occurring naturally as the result of decay or produced by chemical reagents in the laboratory should be distinguished from humus. The term humus, as used in soil chemistry, is simply an empirical term for an alkaline extract of the soil made in a certain way. This extract contains the dark-colored humin substances of the soil, but it also contains other nitrogenous bodies. From the alkaline soil extract known as humus, acids precipitate humin bodies, and on filtering a portion of the nitrogen extracted is found in the acid filtrate.

The melanins, the resemblance between which and the humin bodies has been noted, are the dark-colored pigments found in hair, skin, the choroid coat of the eye, and in certain abnormal tissues, such as sarcoma. They are amorphous bodies, and so far as known do not give any special reactions. They differ in composition according to the source, and agree only in having a high carbon and low hydrogen content. Analyses of many of these have been made, some of which are given below.

Composition of melanins from different sources.

Source of melanin.	C.	H.	N.	S.	Fe.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per ct.</i>
Sarcoma ^a	55.76	5.95	12.3	8.9	0.06
Hair ^b	52.74	3.33	10.51	3.34	.....
Skin, negro ^c	51.83	3.86	14.01	3.6	.....
Sepia ^c	56.34	3.61	12.34	.52	.....
Melanoidin ^d	66.27	5.49	5.57	.0	.....
Do. ^d	60.34	4.86	8.09	.95	.....

^a K. A. H. Mörner, *Ztschr. Physiol. Chem.*, 11 (1887), p. 66; 12 (1888), p. 229.

^b Abel and Davis, *Jour. Expt. Med.*, 1 (1896), p. 361.

^c M. Nencki and N. Sieber, *Arch. Expt. Path. u. Pharmacol.*, 24 (1887), p. 17.

^d O. Schmiedeberg, *Ibid.*, 39 (1897), p. 1.

On precipitating the humin substance or melanoidin from a humus extract of the soil made with 5 per cent caustic soda with hydrochloric

^a *The Chemistry of Vegetable and Animal Physiology.* Trans. by D. P. H. Fromberg, Edinburgh and London, 1849, p. 153.

^b L. V. Udránszky, *Ztschr. Physiol. Chem.*, 11 (1887), p. 537; F. Hoppe-Seyler, *Ibid.*, 13 (1889), p. 66; O. Schmiedeberg, *Arch. Expt. Path. u. Pharmacol.*, 39 (1897), p. 1; F. Samuely, *Beitr. Chem. Physiol. u. Path.*, 2 (1902), p. 355.

^c *Arch. Expt. Path. u. Pharmacol.*, 39 (1897), p. 1.

acid, washing free of acid and drying, there was obtained an almost black body containing 3.16 per cent nitrogen and 18.96 per cent ash. As the humus extract had been passed through a Pasteur filter, the ash constituents were wholly in solution. This ash contained 93 per cent alumina and but a trace of iron. On treating some of the humin substance so obtained with dilute ammonia before drying, a portion was insoluble. The ammoniacal solution on treatment with a slight excess of hydrochloric acid gave a precipitate of humin bodies which on washing and drying was similar in appearance to that first obtained. This body contained 4.9 per cent nitrogen and 8.36 per cent ash.

When the humin substance obtained from a caustic soda extract by precipitation with hydrochloric acid is dissolved in caustic soda and precipitated again with acid, a further quantity of nitrogen is obtained in the acid filtrate. The following figures illustrate this: A humus extract made with 2 per cent caustic soda contained 0.516 nitrogen per cent of soil. On precipitating with hydrochloric acid and washing free of acid there was obtained in the acid filtrate 0.115 per cent nitrogen. A second solution and precipitation gave 0.056 per cent and a third 0.022 per cent nitrogen in the acid filtrate, making a total of 0.193 per cent nitrogen in the humus extract other than in the humin bodies. Although humin bodies from the soil absolutely free of nitrogen have not been obtained, it seems probable that by carrying on the solution and reprecipitation still further this result would be obtained. In any case, the fact that a portion of the nitrogen continues to be extracted by this process indicates that the nitrogen is absorbed rather than in chemical combination in the humin bodies.

In the treatment of pure protein with boiling acids the amount of nitrogen obtained in the magnesia precipitate and classed as humin nitrogen is small; for instance, Osborne and Harris^a give the following among other figures:

Proportion of nitrogen of proteids precipitated by magnesia.

Protein.	Total nitrogen.	Nitrogen in MgO precipitate.
	<i>Per cent.</i>	<i>Per cent.</i>
Wheat globulin	18.39	0.28
Legumin	17.97	.17
Casein	15.62	.21
Gliadin	17.66	.14
Zein	16.13	.16

It is held by some investigators that the formation of humin bodies from protein by this treatment is the result of the action of the acid on some of the primary dissociation products; that is, that they are secondary products.^b By this method the soil studied gave 0.385

^a Jour. Amer. Chem. Soc., 25 (1903), p. 348.

^b L. Langstein, Ztschr. Physiol. Chem., 31 (1900), p. 49.

humic nitrogen in a solution containing 0.735, or 52.3 per cent. The amount insoluble in 12 per cent acids was 0.2, which is probably of humic nature. On the assumption that this is so, the total humic nitrogen is 0.585, or 56.1 per cent. This represents the humic nitrogen in the soil plus that produced by the action of acids. In the chemical analysis of the soil the humic nitrogen was found to be 0.56, or 76 per cent, but, as has already been pointed out, the humic nitrogen includes other nitrogen than that of the humic bodies. Whether the figure 0.585 given above represents approximately the humic nitrogen which would ultimately accumulate in the soil depends on a number of factors, regarding which our information is indefinite. For instance, it is not known how much of the nitrogen insoluble in acids is humic nitrogen, nor to what extent the magnesia precipitate contains other nitrogenous bodies; and very little is known regarding the agents at work in the soil tending toward the destruction of these bodies.

The nitrogen classed as basic and which is precipitated by phosphotungstic acid is, in the case of protein, that of the diamino acids, of which lysin, arginin, and histidin are the most important. Whether any of these or related bodies are included in this classification when applied to soil has not as yet been determined.

The nonbasic nitrogen, which is determined by difference, is, in the case of protein, made up of the monoamino acids, glycocol, alanin, leucin, and aspartic acid being the most important. As in the case of the diamino acids, we know nothing at present as to what bodies are represented in this division when the method is applied to soils.

The results of the application of this method to the soil may be summarized as follows: Boiling with 12 per cent hydrochloric acid, followed by boiling with 12 per cent sulphuric acid, renders soluble 0.735 out of 0.935 nitrogen in the soil. The insoluble portion is probably humic nitrogen; nothing definite is known regarding it. In the solution 16.1 per cent is in the form of ammonia, all in the hydrochloric-acid solution. More than 50 per cent of the nitrogen dissolved is that classed as humic nitrogen, the humic bodies being dark-colored amorphous bodies containing nitrogen and seeming to be related to the dark-colored pigments or melanins occurring in hair, skin, etc. Some of the nitrogen in the magnesia precipitate may not be humic nitrogen as the term is ordinarily understood. It is noteworthy that after treatment with hydrochloric acid more than 92 per cent of the nitrogen dissolved by subsequent treatment with sulphuric acid is included in the humic nitrogen. Of the two remaining classes—basic or diamino and nonbasic or monoamino nitrogen—nothing is known as yet in the application of this method to soil.

While the results from the application of this method are as yet of the most general nature, and very indefinite, it is one which seems to

the writer to promise some light on the constitution of the nitrogenous bodies in the soil. The method has been applied in some of its several modifications to protein by a large number of workers, and most of the decomposition products have been described, both as to composition and constitution, so that in applying it to soil nitrogen one finds a vast amount of information regarding bodies which must be, if not identical, at least closely related to those found in the soil. A study in detail of these bodies included in the several divisions of the classification made by this method is now being made.

ALKALINE SOLUTION.

In treating of the general properties of the soil it was pointed out that treatment with dilute alkalies at the ordinary temperature, as in humus determination, was the only method found of rendering any large proportion of the nitrogenous compounds in the soil soluble without the application of heat, or other treatment, by which solution would be accompanied with more or less decomposition.

Treatment with dilute alkaline solutions results in a dark brown, almost black, solution, the so-called humus extract. From this solution mineral acids precipitate the dark colored humin substances as a flocculent precipitate containing nitrogen. The filtrate from this precipitate is dark red and also contains nitrogen. From this filtrate, on neutralizing with caustic soda, there is thrown down a dirty brown gelatinous precipitate containing nitrogen. When the original extract was made with caustic soda this precipitate contains a large amount of alumina. The filtrate from this precipitate, which is yellow, also contains nitrogen. From the original extract there is thus made a separation into three groups, all containing nitrogen: (1) The humin substances, dark colored amorphous bodies soluble in alkalis, insoluble in water and dilute acids; (2) the dirty colored precipitate, soluble both in acids and alkalis, but insoluble in water, and containing dark colored organic matter, as well as a large proportion of mineral matter; and (3) the neutral yellow filtrate. In addition to containing nitrogen each of these on being dried and heated with lime gives the odor of crude pyridin, so that it is evident a portion of the nitrogen in each is in the pyridin ring form.

The following figures were obtained in making this division. A humus extract made with 2 per cent caustic soda solution contained 0.0399 gram nitrogen per 100 cubic centimeters solution. Making this slightly acid with hydrochloric acid, filtering and washing, the filtrate contained 0.0251 gram nitrogen per 100 cubic centimeters original solution. On neutralizing this acid filtrate with caustic soda, filtering and washing, the precipitate contained 0.0168 gram nitrogen per 100 cubic centimeters original solution. Stated per 100 N. extracted this result is as follows: Division 1, 37 per cent; division 2, 42.1 per cent; division 3, by difference 20.9 per cent.

This solution in cold alkali and the division into three groups each containing nitrogen furnishes a second empirical method of studying the nitrogenous compounds of the soil. While the first method, that of dissociation with boiling acids, can give an insight into the constitution of these compounds only indirectly through their dissociation compounds, the second presents a possibility of studying a portion at least of these compounds in solution unchanged. For this reason this method was taken up first in detail.

PYRIDIN COMPOUNDS IN THE SOIL.

Each of the three groups separated from alkaline solution in addition to containing nitrogen has another property in common, viz, that of giving pyridin or its homologues on heating with lime.

It has already been noted that the soil studied gave on dry distillation some pyridin in the alkaline distillate. The alkalinity of this distillate, which is largely due to ammonia, has varied somewhat according to the manner of distillation. In one distillate pyridin was determined by the method of François,^a and there was obtained pyridin 0.0773 per cent of the soil, or nitrogen as pyridin 0.0137 per cent of the soil. This method, which depends on the formation of the aurichlorid $C_5H_5NHCl.AuCl_3$ and its insolubility in ether, gives accurate figures with aqueous solutions of pyridin, but how far it is applicable in the presence of the higher homologues of this body, some of which are evidently present in the distillate, is not known. For this reason this figure must be regarded at present as an approximate one only. The chief point in this connection is the formation of pyridin on dry distillation.

Pyridin was first obtained from the oil resulting from the dry distillation of bones.^b It is also obtained by the dry distillation of bituminous coal, peat, wood, etc. The commercial source at present is coal tar. A number of alkaloids yield pyridin when highly heated, for instance, it occurs in tobacco smoke as a product from nicotine.

With regard to the formation by dry distillation of such substances as coal and peat, some authorities hold that it is due to the reciprocal action of fats and ammonia, the acrolein from the first condensing with the ammonia to form pyridin.^c This would not apply to the formation of pyridin from alkaloids, which are, for the most part, pyridin ring compounds. Samuely^d has shown that the melanoidins or humin substances resulting from the dissociation of protein give pyridin on reduction. For this reason there has been a tendency to

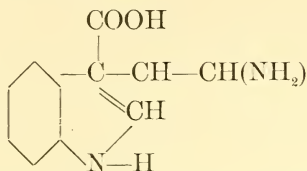
^aJour. Pharm. et Chim., 6. ser., 18 (1903), p. 337; Compt. Rend. Acad. Sci. [Paris], 137 (1903), p. 324.

^bAnderson, Trans. Roy. Soc. Edinb., 20 (1853?), p. 253; abs. in Jour. Prakt. Chem., 54 (1851), p. 36.

^cRichter, Organic Chemistry, Vol. II, p. 528. Philadelphia, 1902, 3. ed.

^dBeitr. Chem. Physiol. u. Path., 2 (1902), p. 355.

assume a pyridin nucleus in the protein molecule. Ellinger^a has, however, suggested for tryptophane, one of the dissociation products of protein, the structural formula



The establishment of this formula would explain the closure of the pyridin ring in protein dissociation products without the necessity of assuming the existence of the pyridin ring as such in the protein molecule. Ellinger states that a genetic relationship exists between tryptophane and pyridin, and quinolin derivatives in plants, such as alkaloids. Hopkins and Cole^b have shown that tryptophane is readily changed to dark colored humin substances on boiling with acids or even with water.

The chief point of interest at this stage is whether the formation of pyridin on dry distillation is evidence of the presence of a pyridin compound in the soil.

Viewed in the light of our present knowledge and the theories stated above, the formation of pyridin on dry distillation may be due: First, to the interaction of fatty material and bodies yielding ammonia; second, from melanoidins or humin bodies; third, from some vegetable residue known to contain a pyridin nucleus; and, fourth, from the decomposition of the lime salt of a pyridin carboxylic acid.

If the formation of pyridin is explained by the first method, it means that the pyridin ring is a condensation product of distillation and does not exist as such in the soil. This supposition does not seem likely, for although ether extract of the soil was 0.005 per cent, the soil yielded pyridin after extraction as before.

The possible connection between tryptophane and pyridin, and the readiness with which the former is converted into melanoidins, have been noted, and we have in this a possible explanation of the formation of pyridin. However, accepting the theory that the pyridin is formed from the humin bodies, our lack of knowledge of the constitution of these bodies still leaves unsettled the question whether the pyridin exists as such in the soil. It should be noted in this connection that no trace of tryptophane has been found in any of the soil extracts.

The formation of pyridin according to the third method stated above means that some vegetable compound containing a pyridin nucleus had resisted decomposition and existed unchanged in the soil.

^a Ztschr. Physiol. Chem., 43 (1904), p. 325.

^b Jour. Physiol., 27 (1901), p. 418; 29 (1903), p. 451.

A large number of alkaloids contain a pyridin nucleus, and it is probable that a large number of plants contain compounds of this character which have not been identified or studied. Moreover, the alkaloids are quite resistant to decomposition, and it would not be an unlikely thing to find alkaloids in the vegetable débris making up the organic matter in the soil. In the case of the soil studied no reactions for alkaloids have been obtained in any of the soil extracts made. The only indication of alkaloids was obtained in the distillate resulting from passing steam through soil covered with a 2 per cent solution of caustic potash. From this distillate, which contained a large amount of ammonia, there was obtained a very small amount of a volatile oily substance having the odor of coniin. No reactions for coniin could be obtained, and the amount has been far too small for identification. Its properties so far as determined point to some product of bacterial action related to the ptomaines putrescin and cadaverin.

With regard to the fourth method it is characteristic of a large number of pyridin carboxylic acids that the lime salts of these acids or the acids themselves when heated in contact with an excess of lime give pyridin. This applies also to the carboxylic acids of the homologues of pyridin, the corresponding homologue being obtained. Theoretically this is the simplest explanation of the production of pyridin on dry distillation of the soil. As the total amount of lime in the soil is small and apparently all in combination, this explanation would hold only in the presence of a lime salt of a pyridin carboxylic acid or a similar acid of some homologue of pyridin.

It would seem, then, that the pyridin obtained on dry distillation of the soil is due either to some obscure reaction involving the humin bodies or to the decomposition of the lime salt of some pyridin carboxylic acid.

NEUTRAL SOLUTION.

Returning now to the alkaline solution and the empirical divisions made of it we find that in division 3 we have a neutral solution containing a portion of the nitrogen extracted from the soil. The manner of making the extract and subsequent divisions; treatment with dilute alkalis and acids without the application of heat, is such that it is safe to conclude there has been no change of constitution; or, in other words, that any compound which appeared in the final neutral solution would be the same compound actually present in the soil, the only change being that of combination. A study of this neutral solution offers then the readiest method of arriving at the constitution of some of the nitrogenous bodies in the soil. Working with a solution made with 5 per cent caustic soda and making the division using nitric acid instead of hydrochloric as outlined above the following results were obtained with the neutral filtrate.

On being concentrated to small bulk a small amount of dark flocculent apparently humin substance was precipitated. The filtrate from

this gives a voluminous white precipitate with silver nitrate. This precipitate becomes darker on exposure to light and is soluble in ammonia. On decomposing this precipitate with hydrogen sulphid and concentrating the filtrate from silver sulphid to small bulk crystals were obtained quite soluble in hot water, but difficultly soluble in cold. On repeating this process several times the crystals were obtained almost free from color.

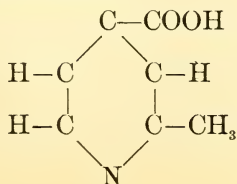
Lead acetate gives with the neutral solution in most cases a slight precipitate, apparently coloring matter. On filtering from this and adding ammonia there is thrown down a heavy yellowish precipitate consisting, of course, in part of basic nitrate. On decomposing this with hydrogen sulphid, neutralizing free nitric acid with ammonia, concentrating to small bulk, adding silver nitrate, and treating the precipitate so obtained as above the same crystalline preparation was obtained. This precipitation with ammoniacal lead acetate and subsequent precipitation with silver nitrate was found to be a readier method of obtaining crystals free from color than direct precipitation as the silver compound.

The crystals prepared in this way, as already stated, are soluble in hot water, little soluble in cold. They are very little soluble in alcohol and insoluble in ether. From solution in hot water on cooling oblique prismatic crystals separate having a very peculiar appearance, giving en masse the impression of being slices or scales and resembling somewhat crystals of benzoic acid. On rapidly cooling a hot, very dilute solution minute crystals, regular in form, are obtained, as shown in Plate III, figure 2.

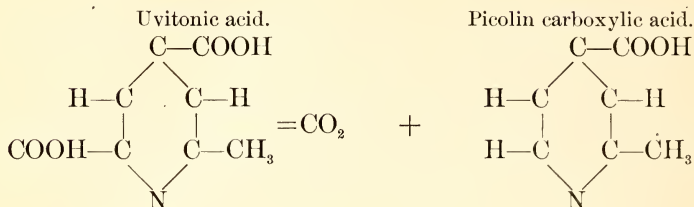
This preparation when heated in an open watch glass sublimes without melting and leaves no residue. The sublimate was found to be the same substance unchanged. Heated in a capillary tube it does not melt at 300° C. The water solution gives no color with ferrous sulphate, and is very faintly acid. The solution neutralized with ammonia gives no precipitate with either barium chlorid, calcium chlorid, cadmium sulphate, or lead acetate. Cupric acetate gives a dark bluish crystalline precipitate insoluble in cold water. With hydrochloric acid a compound is formed crystallizing in prisms.

PICOLIN CARBOXYLIC ACID.

The properties of this substance as thus determined point to its being picolin carboxylic acid, or methyl pyridin carboxylic acid. The structural formula of this is:



This acid has been described by Böttinger^a and was prepared by him by heating uvitonic acid (methyl pyridin dicarboxylic acid) to 274° C. This breaks up as shown below:



The identification of this body has been confirmed by the following determinations. Picolin carboxylic acid crystallizes with one molecule of water of crystallization which it loses at 100° C. A determination of the water of crystallization of the acid from the soil gave 11.34 per cent while that calculated from the formula $\text{C}_5\text{H}_7\text{NO}_2\cdot\text{H}_2\text{O}$ is 11.62 per cent. The hydrochlorid gave Cl 20.50 per cent the calculated Cl for $\text{C}_5\text{H}_7\text{NO}_2\text{HCl}$ being 20.46 per cent. Nitrogen in the acid, free of water of crystallization, was found to be 10.02 per cent, that calculated for $\text{C}_5\text{H}_7\text{NO}_2$ is 10.21 per cent. The acid from the soil on oxidation with permanganate of potash yields a body crystallizing in leaflets little soluble in cold water and melting at 239° C. The water solution of this body gives a yellowish orange color with ferrous sulphate. These properties correspond to those of lutidinic acid, one of the pyridin dicarboxylic acids; the picolin carboxylic acid on oxidation yielding lutidinic acid by the oxidation of the methyl group to carboxyl, thus, $\text{C}_5\text{H}_3\text{N}, \text{CH}_3, \text{COOH} + 2\text{O}_2 = \text{C}_5\text{H}_3\text{N}(\text{COOH})_2 + 2\text{H}_2\text{O}$.

This close agreement between the theoretical and determined figures and the properties as determined is sufficient to establish the identity of the substance as picolin carboxylic acid.

The pyridin carboxylic acids include a large number of compounds. Pyridin has five hydrogen atoms replaceable by the carboxyl group. Theoretically there are 19 of these acids possible, all of which are known. All are laboratory products, many of them prepared from alkaloids. In the pyridin ring each of the hydrogen atoms is also replaceable by other groups, e. g. methyl. When this takes place together with replacement of one or more hydrogen atoms by carboxyl we have methyl pyridin carboxylic acid to which group the acid obtained from the soil belongs. Hydrogen atoms in the pyridin ring may also be replaced by other groups so that the possible carboxylic acids is very large. So far none of the pyridin or methyl pyridin carboxylic acids have been found in any plant or natural

^aBer. Deut. Chem. Gesell., 14 (1881), p. 67; 17 (1884), p. 92.

product but have all been obtained from other related bodies by chemical means.

There have been six isomeric methyl pyridin carboxylic acids described, picolin carboxylic acid having the CH group in the 2 or α position and the COOH in the 4 or γ position.

In its method of preparation picolin carboxylic acid is of interest in that it can be prepared from its elements. As stated it has been prepared by heating uvitonic acid. This is prepared by the action of ammonia on pyrroacemic acid which is obtained by heating racemic acid. This in its turn can be prepared from its elements in a number of ways, ethyl alcohol or carbon monoxid, both of which can be synthesized, being the starting point.

The amount of this acid obtained in a pure form from the soil by the method stated has been small, it being necessary to work with several kilos of soil to obtain enough for the determinations made. No attempt has been made to make quantitative determinations, and the amount obtained has been two to three hundred parts per million of soil, several times the amount of nitrates present under the most favorable conditions.

Picolin carboxylic acid has been obtained from several other Hawaiian soils, including one very heavy clay soil containing but 0.06 per cent nitrogen, so that it would seem not to be confined to highly organic soils.

Mainland soils in quantity have not been available for examination; however, from small samples on hand of soil from eastern States, small quantities of crystals were obtained having the appearance, physical properties, and behavior in solution of those of picolin carboxylic acid.

RELATION OF PYRIDIN COMPOUNDS TO AGRICULTURE.

It is common in Hawaii for farmers to find virgin soil, especially on the uplands, unproductive for the first years of cultivation. In some cases nothing will grow, as might be expected from conditions of soil and climate, and again certain crops will grow and others will not. This condition is generally relieved by cultivation, but in some cases not wholly so. Various explanations have been given for this condition, including ferrous iron, soil acidity, and lack of one or more of the elements necessary as plant food; but in most cases such examinations as are made in chemical laboratories have failed to reveal anything of this nature. For this reason there is in the minds of very many who have attempted to grow crops in Hawaii a confirmed conviction that there is in such cases something poisonous in the soil. Somewhat similar conditions have been observed in limited locations elsewhere. Aside from this, however, there are many facts in regard

to the rotation of crops and the effect produced by certain fertilizing materials, such as stable manure, effects wholly out of proportion to their value as determined by analysis, forcing the conclusion that there exist a whole series of phenomena regarding the relations of plants to the soil that are unexplained and even unmentioned in the current teachings regarding available plant food and fertilization. These general considerations, coupled with exhaustive studies of special soils, have led to the conclusion that in many cases soils do not produce crops for the reason that they contain some body poisonous to the crop grown and not because of lack of plant food.^a It is not known whether such poisonous bodies are excretions of plant roots or the result of bacterial action on organic compounds in the soil.

It has already been noted that many poisonous alkaloids are pyridin compounds. These alkaloids are plant products and are found in many cases deposited in the seeds. The chemical reactions which precede the secretions of these poisons in the plant are not known, and although they must exist as such in some part of the plant, it is evidently in such form or such place that the life processes of the plant are not interfered with. Experiments indicate that in the germination of seeds containing poisonous alkaloids these nitrogenous compounds are not reassimilated,^b and so far as the plant is concerned they seem to be either excretions of material for protection or depositions in an insoluble form of material which would injure living protoplasm.

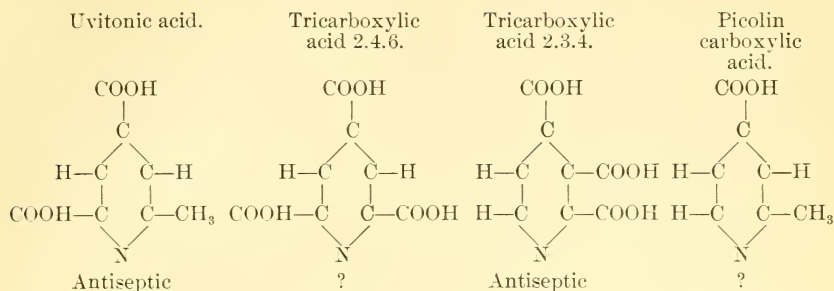
Many fungi can grow on dilute solutions of poisonous alkaloids, and it can not be assumed that because a compound is poisonous to higher animals it will prove so to plants. This can only be determined by experiment.

With regard to picolin carboxylic acid, it is of interest to note its family connections. Uvitic acid, from which it can be prepared by heating and which differs in composition only by CO_2 and in constitution only by having one COOH group in the place of one H atom, is known to be a strong antiseptic. Further, uvitic acid on oxidation with alkaline permanganate yields a pyridin tricarboxylic acid. There are five possible isomeric pyridin tricarboxylic acids, the one obtained from uvitic acid having the carboxyl groups in the positions 2, 4, 6. Another member of this group, having the carboxyls in the positions 2, 3, 4, is also known as an antiseptic, and has been

^a U. S. Dept. Agr., Bureau of Soils Bul. 28. M. Whitney, U. S. Dept. Agr., Farmers' Bul. 257.

^b De Vries, Landw. Jahrb., 7 (1878), p. 243. Wotezal, Bot. Jahrb. 41, p. 100. G. Meyer, Bot. Centbl., Beihefte, 6 (1895), p. 61. Heckel, Compt. Rend. Acad. Sci. [Paris], 110 (1890), p. 88.

recommended as such in medicine.^a The structural relationship between these is shown below:



These facts are suggestive, and it would seem very probable some of the pyridin carboxylic acids might have a detrimental effect on growing plants.

With regard to picolin carboxylic acid, which seems to be a normal constituent of soils, no conclusions have yet been reached either respecting its antiseptic properties or its effects on living plants. Investigations covering these points are being now carried on.

In considering the relation of picolin carboxylic acids to agriculture, there are two points which should be especially considered. First, the solubility of nearly all its salts, although the acid itself is little soluble. Experiments indicate that these soluble salts are readily absorbed by the humin bodies, but to what extent has not yet been determined. The second point is that while it is an acid in constitution in virtue of having a carboxyl group, and forms salts with bases, it at the same time can act as a base and forms compounds with mineral acids by direct addition. All of the pyridin carboxylic acids having but one or two carboxyls have this characteristic, and it is only when the number of carboxyls is increased, as in the penta acid, that the power of uniting with strong acids is lost and the acid character becomes prominent. Picolin carboxylic acid, then, is not one which could be considered a factor in considering soil acidity, or the dissolving, or rendering "available," the mineral matter in the soil.

^a C. J. Rademaker, Med. Herald, 19 (1887), p. 107.

THE ECONOMIC SEAWEEDS OF HAWAII AND THEIR FOOD VALUE.

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Hawaii has nearly a thousand miles of coast line; as a consequence the native Hawaiians are skillful and daring fishermen and sailors, as well as splendid swimmers. The Hawaiians, like the Japanese, are fond of almost all the products of the sea, and, like them, prize the seaweed very highly for food. Ancient Hawaiians probably seldom ate a meal without some kind of limu^a or seaweed, and even to-day no Hawaiian feast is considered quite complete without several varieties served as a relish with meats or poi.^b

Many tons of these seaweeds are gathered and eaten by the Hawaiians annually, besides large quantities are imported from the Orient and San Francisco for the consumption of both the Japanese and Chinese. The seaweed sold in Honolulu alone amounts annually to thousands of dollars.

Before the coming of the white man to these islands the diet of the poorer Hawaiians was largely poi, fish, and limu. Even poi was scarce in times of war or famine, and then the poorer fishermen contented themselves with only fish and limu. Sometimes for weeks no other vegetable food could be obtained but limu, which can be gathered all the year, except during very severe storms. Sweet potatoes, taro, and bananas could only be grown in the good soil, where there was plenty of rain or sufficient water for irrigation. Many of the fishing villages had no fertile land near them, so these people were compelled to go to the mountain valleys to secure all their food except what they fished from the sea. Until the death of Kamehameha the Great (1819) women suffered the death penalty if they ate bananas, cocoanuts, turtles, pork, or certain fish, so that their diet was even more limited than that of the men. They must have suffered greatly during times of famine and war, when their only food came from the

^a Limu is the Hawaiian name generally applied to all water plants, and is equivalent to our word algæ. They sometimes include various pond weeds, or fresh-water limu, as nitella, chara, etc. Usually limu means either fresh or salt water algæ that are edible.

^b Poi is a thick paste made from the root of the taro plant (*Colocasia esculentum*), and takes the place of rice or bread in the native diet. It is made by pounding the moistened boiled or steamed roots with water to smooth paste, which is then slightly fermented.

sea. Before the coming of the missionaries there were no fruits except bananas, cocoanuts, and the mountain apple, and none of these were ever abundant, except the mountain apple or ohia,^a which is plentiful only during July and August in the mountain valleys wherever there is a heavy rainfall.

It was because of this limited food supply, no doubt, that the early Hawaiians learned to use for food almost every living thing, both plant and animal, found along their coasts. Almost every kind of seaweed that could possibly be eaten was used for food by some Hawaiians, while certain of the more attractive algæ were universally used wherever and whenever it was possible to secure them from the sea. The people living in the mountain valleys used, in addition to marine algæ, several kinds of the soft green fresh-water algæ from the streams and ponds. Nothing edible, from tiny shellfish or minnows an inch long to great sharks, escaped the hungry Hawaiian fisherman. Likewise he gathered seaweeds, large and small, and also the fine green algæ of the fresh water to satisfy his hunger for vegetable food. The limu had to take the place of all green vegetables—as onions, lettuce, beets, beans, peas, etc.—as well as fruits, and must have helped very much to vary the monotony of a diet of fish and poi, which were then as now the two staple foods of the native Hawaiians.

There are over seventy distinct species of algæ or limu used for food by the Hawaiians. Of these seventy species not more than forty are in general use. The other thirty or thirty-five are used only by a few people in certain small areas where they are found in limited quantities. There are perhaps a dozen or more common species of algæ, mostly marine, that are termed by the Hawaiians simply limu, or with some descriptive appellation, like limu make, meaning poisonous limu. Each edible limu has its own special appellation besides the generic name limu with which it is combined either as a descriptive adjective or as a suffix.

The following notes and observations have been collected during the last three years from various sources, and from personal study in the markets and along the beaches wherever the limu gatherers were at work collecting or preparing algæ for food. In addition to this, much information has been secured from Hawaiian friends who have very kindly assisted the writer in various ways in collecting both the specimens and data. The writer is especially indebted to Mrs. Emma Metcalfe Nakuina, Mrs. W. L. Bowers, Mrs. Elizabeth Kahanu Gittle, Mrs. Rosina Shaw Leslie, Mrs. Kepoikai, Mr. B. K. Kaiwiae, Mrs. Deverel, Judge Kahele, and many others for the native names, specimens for study, and descriptions of the methods of preparing them

^a *Eugenia malaccensis*, in the valleys and mountain slopes in the lowest forest zone. Fruit sweetish, juicy, about size of early June apple, and resembling a red apple, except in flavor.

for food. A number of the pupils of the Kamehameha schools from different islands have, with the aid of their relatives, helped secure specimens of their edible algæ with the native names. They have also furnished many notes on the preparation and preservation of algæ for food. The writer is also very greatly indebted to Dr. W. A. Setchell, of the University of California, for identifying and verifying many specimens, and to R. A. Duncan, food commissioner and chemist of the Territory of Hawaii, for analyzing the edible algæ and for the use of his library.

The following publications have been consulted for tables of analyses and other data: U. S. Dept. Agr., Office of Experiment Stations Circular 46 (rev.), by C. F. Langworthy, Ph. D.; Office of Experiment Stations Bulletins 68, 107, and 159; United States Dispensatory; Analyses of Taro and Poi, report of Dr. E. C. Shorey when food commissioner and chemist of the Territory of Hawaii; Postelsia, the Yearbook of Minnesota Seaside Station, 1901; and Seaweed Industries of Japan and the Utilization of Seaweeds in the United States, by Hugh M. Smith. Bul. [U. S.] Bureau of Fisheries, 24 (1904).

METHODS OF GATHERING LIMU.

Most of the limu is gathered by native women and children, except that which grows in the deeper or rougher water, far out on the coral reefs, or on exposed rocks, where expert swimming and more strength are required, and also where a boat is usually needed. In such places at least two people are required, and often a party of three or more men and women go together. The women usually gather the limu while the men are fishing and caring for the boat and nets.

The limu gatherers go out at low tide with tin pails, old sacks, and pieces of sharpened iron or an old knife, and scrape the seaweed from the coral or rocks. The seaweed is freed from sand and pebbles and each kind placed in a separate receptacle, if possible. If the limu grows nearer shore in the sand or mud, or floats in near the beach, the women and children wade out, gathering it without any implements, carefully washing out the sand, mud, or small sea animals, and pulling out all inedible limu before placing it in their pails or sacks. They often wade out into the water above the waist, following the tide as it recedes. A few varieties of limu drift ashore, and are simply gathered along the water's edge from the rocks and sand and shaken free from the sand or inedible weeds. The following varieties are often found drifted on the sand or rocks: Limu huna (*Hypnea nidifica*), limu manaua (*Gracilaria coronopifolia*), limu kala (*Sargassum echinocarpum* and *S. cymosum*), and limu lipeepee or limu maneoneo (*Laurencia papillosa*, *L. pinnatifida*, *L. virgata*, *L. obtusata*, and a few other species of *Laurencia* not yet identified).

Limu uualoli (*Gymnogongrus vermicularis* var. *americana* and *G. diciplinialis*), limu kohu (*Asparagopsis sanfordiana*), limu aalaula (*Codium muelleri* and *C. tomentosum*), limu lipoa (*Dictyota acutiloba* var. *distorta* and *Haliseris plagiogramma*), and limu lipeepee of several varieties grow far out on the coral reefs or on exposed rocks in the surf. These all have rather tough, firm holdfasts, and a stout sharp knife or chisel is required to loosen them from their supports and strong swimmers to gather them. Those named above are usually gathered by a party in a boat, though sometimes the limu gatherers venture far out on the shallow coral reefs with only their pails or bags and their chisels.

The following varieties of limu grow quite near the tide line along shore, but on exposed black lava rocks in rough water: Limu akiaki (*Ahnfeldtia concinna*), limu loloa (*Gelidium capillacea*, *G. corneum*, *G. filicinum* (?), *G. pulvinatum* (?), *G. latifolium* (?), *G. attenuatum* (?), and *Pterocladia capillacea*), limu uualoli (*Gymnogongrus disciplinalis*), and limu luau (*Porphyra leucosticta*). These all have very tenacious holdfasts, so generally require a strong, skillful swimmer with a knife or chisel to gather them in large quantities.

Those growing near shore in quiet waters in sand or mud or on small stones are easily gathered with only the bare hands, and usually the older women and children gather these varieties, while the men and the younger strong women gather the varieties growing in the rougher or deeper water. The following are the varieties easily gathered near shore: Limu eleele^a (*Enteromorpha prolifera*, *E. linza*, *E. intestinalis*, *E. prolifera* var. *tubulosa*, and *E. plumosa*), limu huna (*Hypnea nidifica*), limu manaua (*Gracilaria coronopifolia*), limu pakaeleawaa or limu huluhuluwaena^b (*Grateloupia filicina*), limu huluilio (*Chaetomorpha antennina*, *Ectocarpus* sp. (?), *Centroceras clavulatum*, and *Stigeoclonium amœnum*), limu pahapaha^c (*Ulva fasciata* and *U. lactuca* var. *rigida*), limu oolu (*Chondria tenuissima* var. *intermedia*), and limu puaki (*Liagora decussata*). There are besides a few other species found only in small quantities, or in certain localities, and only eaten by the Hawaiians in remote districts, or by a small group of families who alone seem to appreciate their flavor. Limu luau (*Porphyra leucosticta*) is one of these which appears in winter or spring after heavy

^a Limu eleele is applied to a number of slender thread-like green algae growing near the mouths of streams in brackish water. Most of them are Enteromorphas. On Maui the edible Enteromorphas are called by some natives limu pipilani.

^b Limu huluhuluwaena is the native name for *Grateloupia filicina*, generally used on the island of Hawaii and in frequent use on Maui and Oahu, while limu pakaeleawaa is the name always used on Kauai and in common use on Molokai, Maui, and Oahu.

^c Limu pahapaha is applied to several Ulvas on Oahu, Molokai, Maui, and Kauai, while limu pakaiea is the name for the same Ulva on Hawaii.

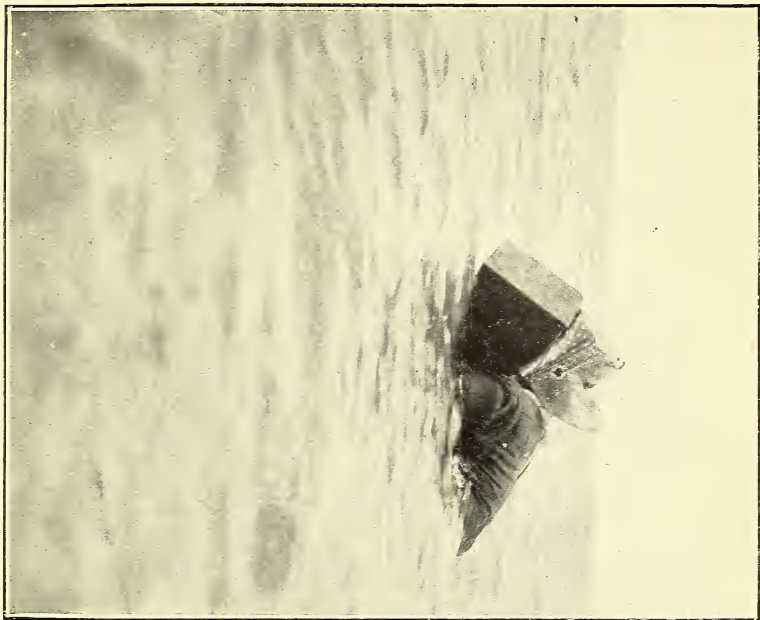


FIG. 1.—USING GLASS-BOTTOMED BOX TO SEARCH FOR LIMU.



FIG. 2.—CLEANING AND PREPARING LIMU.

storms and last for only a few days. It is found on bold exposed rock constantly dashed by waves, so it is difficult and dangerous to collect it, especially as it is extremely slippery and has to be scraped forcibly from the rocks in small bunches while the collector clings to his support and avoids the heavy waves. He must be sure-footed, quick, and a strong swimmer, if he collect limu luau. Limu eleele must always be floated or dipped out of the water into pails, because it always grows at the mouth of streams in the quiet brackish water, so is full of silt or sand. This is partly washed out as the limu is scraped or floated out with the hands into the pails. This limu is very fine and slippery, like hair, so it must be handled in a different manner from other algæ, and requires much more care to remove the sand, the small, clinging mollusks, and crustaceans.

Occasionally you will see a limu gatherer out on the reef, in water almost to her waist, looking very intently through a square glass-bottomed box, and now and then probing the depths with a sharpened iron rod. The iron rod is used to loosen certain mollusks, limu uāualoli, limu lipoa, limu maneoneo, and also to kill eels and octopi, all of which are highly prized for food. The boxes or square frames with a glass bottom have been recently introduced by the Italian fishermen, and are not in general use even near Honolulu. In Plate IV, figure 1, will be seen a limu gatherer looking through the glass box, probing with the iron bar, with a large bag suspended from her neck, into which she thrusts her limu, mollusks, or squid.^a

At low tides, when the water recedes, wherever there are flats or shallow coral reefs and quiet water, one can see many natives with bags and old knives wading far out gathering limu and other sea edibles, as mollusks, squid, sea urchins, and sea cucumbers or bêche de mer.

NATIVE METHODS OF PREPARING AND SERVING LIMUS FOR FOOD.

Immediately after gathering the limu it is very carefully washed, either in salt or fresh water, to remove all sand, mud, or clinging mollusks and crustaceans. The Hawaiian women are most particular about this cleaning process, so wash the seaweed through many waters, and look it over very carefully to remove every particle of grit or inedible limu that often becomes entangled with the edible varieties. (See limu cleaning in Plate IV, figure 2.)

A few varieties of limu can not be washed in fresh water without injuring the flavor and causing a very rapid decay, so that in a few hours it is entirely unfit for food. The following are the very perishable varieties that must be cleaned in salt water and eaten soon after

^aThe term "squid" is universally applied to the common octopus, *Octopus octopodia*.

preparation: Limu oolu, limu lipeepee, limu lepeahina (*Halymenia formosa*), limu moopuna-ka-lipoa (*Griffithsia* sp.?), and probably a few others not in general use.

After cleaning, the seaweed is always salted and usually broken, pounded, or chopped into small pieces, and usually it is eaten uncooked as a relish with poi, meats, or fish. Raw fish is never eaten without limu or some other relish, such as raw tomatoes, chili peppers, or onions.

The Hawaiians in the ancient times seldom cooked their limu, though it was occasionally placed in the imu or earthen pit with pig or dog and roasted or steamed. This was done when there was a famine or war and taro and sweet potatoes were scarce. Limu akiaki, limu huna, limu manauca, and limu uualoli were all sometimes cooked in this way as a substitute for taro and sweet potatoes.

The Hawaiians of to-day do far more cooking than formerly, because they are not hampered for cooking utensils as their ancestors, who had no vessels that could be set over the fire. Water could only be heated by putting in hot stones, and boiling or stewing was almost impossible. Their only method of cooking meats or fish was in the primitive imu, or pit lined with stones and heated with a big fire. This when well heated was lined with banana and ti^a leaves, then pigs, dogs, fish, taro, or sweet potatoes were placed on the ti leaves, covered well with ti and banana leaves, while over this was heaped earth. This was allowed to steam twelve hours or more before serving. Usually hot stones were placed in the pig to hurry the cooking, or if the pig was large it was cut into small pieces for each individual. These small pieces with a roll of taro leaves or some gelatinous limu were placed in ti leaves and tied in bundles, which were placed in the pit and roasted as described above. The limu when steamed in this way with meats becomes gelatinous and is flavored with the meat juices. It is considered very delicious by the natives, who always eat it with the roasted meat and sweet potatoes.

Very few poor Hawaiians have stoves or ovens, so that all their baking or roasting is still done in the primitive way. Their cooking is done over a fire in an old coal-oil tin out of doors, hence must be very simple. Meat is usually boiled or stewed in small quantities with taro leaves or limu. Whenever any Hawaiian gives a large dinner the pig and fish are roasted in the imu as in olden days. The following limus are often cooked with boiled meats or put into soups or gravies for thickening and flavoring, as well as with roast pig in the imu: Limu akiaki, limu uualoli, limu loloa, limu lipeepee, limu

^a *Cordylone terminalis*, found on the mountain sides on the edges of the forest. The leaves are used instead of paper for wrappers for food, and for plates, etc. The root is roasted and eaten and is also fermented into a kind of strong drink like rum.

kohu, limu lipoa, limu eleele, limu pahapaha, limu huna, limu manaua, limu aalaula, and limu kala. The tougher, more cartilaginous ones are boiled long enough for the gelatin to be softened or dissolved, as limu akiaki, limu huna, limu manaua, limu uualoli, limu loloa, and limu lipopee, while the others are only dropped into the hot soup or gravy just as it is about to be served.

Limu huna is especially prized for boiling with squid or octopus, though limu manaua and limu akiaki are often used as substitutes. These limus, when boiled with squid, produce a jelly of which the Hawaiians are very fond. Limu manaua is considered by native cooks especially fine when boiled with chicken, as it thickens the broth. Sometimes grated cocoanut and cocoanut milk are added to the chicken, forming a very delicious fricasse, which the writer has tested with very great appreciation. The writer has tried nearly all of these gelatinous limus with boiled beef and in beef or other soups, and finds them excellent. They are particularly palatable in vegetable soups, and are probably equally good in chicken or mutton broth, where the limu would make an excellent substitute for tapioca or sago, so often used by American cooks. Limu eleele, being a general favorite and so widely distributed, forms a part of every native feast. After being thoroughly soaked and washed in fresh water it is salted slightly and served uncooked, with poi and fish or meats. It is sometimes put into hot gravy or broth and in meat stews just before being served. It may be kept with a little salt about a week. Some natives allow it to pass through what they call a ripening process, which is as follows: The limu is soaked twenty-four hours or more in fresh water after being cleaned, when it begins to change color, becomes yellowish, slimy, and decomposes somewhat, developing a very rank odor. It is then said to be ripe and ready to eat. When sold in the market it is usually freshly prepared the day before, so is generally eaten without ripening or decomposing.

Limu aalaula, Limu kala, limu moopuna-ka-lipoa, and sometimes limu pahapaha pass through very much this same process of ripening before they are served by some of the Hawaiians in certain localities. Limu kala when ripened in this way is separated from the stems and floats, as only the leaves are eaten. Limu kala is more often eaten fresh and without any preparation whatever. Just as it is taken from the sea it is broken into convenient pieces and serves as a relish with raw fish or squid, which are frequently eaten on the beach as soon as they are taken out of the water and almost before they are dead.

The edible fresh-water algæ are often subjected to the ripening process described above. There are a number of these fine green algæ much alike in appearance called limu palawai, or lipalawai, limu nehe, and limu haulelani, which are usually found in the cool, swift mountain streams or pools. They are all the green threadlike forms of *Cladoph-*

ora nitida, *Spirogyra* sp. (?), *Hydrodictyon reticulatum*, *Pithophora affinis*, *P. polymorpha*, *Stigeoclonium amicum*, *S.* sp. (?), and other species unidentified, probably *Spirogyra* and *Cladophora*. These fresh-water algae are sometimes taken fresh from the stream and eaten with fresh-water shrimps or opai and a little salt. These fresh-water limus are also occasionally cooked with pig in the imu, or put into the gravy. Most of the fresh-water algae are eaten by the natives living in the mountain valleys, as the people on the beach seem to prefer their own more accessible seaweeds.

There is a flowering plant found in fresh-water ponds that is eaten by the Hawaiians with great relish, especially with raw opai. This flowering plant (*Naias major*) is called limu kala-wai because it resembles slightly the limu kala from the sea. It is eaten raw with a little salt, much as water cress. It is considered particularly appetizing with raw fresh-water shrimps, opai, or crabs. It is often sold in the market during February and March, when it seems to be most abundant.

Limu lipoa is very often pounded and mixed with other seaweeds to give them its peculiar penetrating, spicy flavor and odor. It is frequently served with meats or put into the gravy or stews to give to them a peppery flavor, of which the Hawaiians are very fond. All Hawaiians like the odor and flavor of this alga, especially with raw fish. It is considered particularly delicious with raw flying fish, if simply broken and salted slightly. This seaweed has a very agreeable spicy taste and odor, and undoubtedly takes the place of sage and pepper in Hawaiian foods.

Limu kohu is always pounded well as it is being cleaned to free it from adhering bits of coral, and also so that it may be soaked more thoroughly to remove the disagreeable bitter flavor. It is soaked twenty-four hours or more in fresh water, to remove the bitter iodine flavor. It is then salted ready to be served as a relish or salad with meats, fish, and poi, or it is mixed with other seaweeds and put into hot gravy and meat stews, just as many other limus are eaten. Limu kohu has a rather pleasant flavor, though it is slightly bitter even after soaking twenty-four hours. It is always found in the market made into balls about the size of a large baseball and heaped upon large plates. It sells at 25 cents per ball and is always in great demand.

A very delicious condiment called inomona is made of the roasted kernel of the kukui^a nut pounded fine with salt. Many Hawaiians also add a bit of chopped chili pepper and some limu, usually limu kohu, which is pounded very fine and then thoroughly mixed with the

^aThe kukui tree or candlenut (*Aleurites mollucana*) grows abundantly in our mountain valleys and mountain sides, bearing oily nuts, which were strung on grass and burned for torches or candles in ancient times. The oil was extracted and burned in stone lamps. The nuts are edible if roasted.

pounded kukui nuts and salt. This will keep for months in glass jars, and is excellent with bread and butter or cold meats. It resembles Russian caviare in flavor, especially when eaten with bread and butter. The Hawaiians serve this with poi, raw or cooked fish, or roast meats as a relish or condiment. Other limus as limu lipeepee or limu manaua are also sometimes used in making inomona, and if chili peppers can not be obtained, the large green peppers are cooked in ti leaves, then pounded and used instead. The dried gills of the squid roasted in ti leaves are also added by some Hawaiians.

Limu luau or limu lipahee, as it is called in Hawaii (*Porphyra leucosticta*), is prepared by washing in the usual way in fresh water. It is then salted a little and put into clear water, where it becomes slippery and colors the water a lovely violet color. Sometimes opihi, a kind of limpet or mollusk, is put in with the limu and salt and water and placed in bottles or jars. This is used as needed, for it keeps many weeks when placed in the weak brine with the limpets. The tender tips of limu pahapaha are sometimes prepared by rubbing and crushing between the fingers, and then it is mixed with small mollusks of a special kind and salt. The finely pounded limu uualoli is sometimes mixed with salt and small limpets in very much the same way.

The soft parts, particularly the eggs and sperm, of several kinds of sea urchins are salted and mixed with limu uualoli, limu kohu, or other pounded limus, and this mixture is served and always eaten raw for a relish or entr  . In the same way loli (several species of holothurians, as sea cucumbers, b  che de mer, and others) are cut into small pieces and mixed with pounded limu, salt, and sometimes a little chili pepper is added and then served uncooked.

Limu lipahapaha is sometimes boiled with squid, just as limu huna, and forms a gelatinous mass when cold. Limu ekahakaha is sometimes simply pounded and mixed with limpets and sometimes it is cooked with the limpets and seasoned with chili peppers and salt.

Limu aalaula is often pounded very fine and mixed with pounded salted squid, while chili peppers may also be added if preferred. It is also sometimes pounded with other seaweeds to be eaten with poi and fish or meats.

Limu kala is sometimes broken into small pieces and soaked in fresh water until it turns dark and soft, then stuffed into salmon before it is roasted, or it is chopped with fish heads and salt. Again it is sometimes ripened by putting in water with a few mollusks called leho, salted slightly, and allowed to stand several days before eating. Limu kala is more often than any other limu eaten on the beach, without any preparation other than rinsing off the sand and breaking into convenient pieces for eating with raw fish or squid. It is also sometimes put into meat gravies or stews just as it is served.

Limus when eaten raw and crisp with a little salt, or with chopped

chili peppers added, are very pleasant appetizers with meats or fish. The writer thinks that the Americans and Europeans would find them more palatable with the addition of vinegar or lemon and pepper, or possibly an oil dressing. They serve much the same purpose in the Hawaiian diet as our salads, and certain varieties certainly have a very pleasant saline flavor and crispness.

Sometimes various shellfish, as crabs, shrimps, small mollusks, and holothurians or sea cucumbers, are chopped into small pieces and then mixed with the pounded limu and salt and often bits of chili pepper are added to the mixture. This is served with poi, meats, or fish.

Certain seaweeds are always used with certain kinds of fish or mollusks, because their peculiar flavors are considered best when blended together. Shellfish and mollusks are usually eaten raw, and that is probably why chili peppers are usually added, just as with raw fish, to sharpen the flavor, which alone is rather insipid.

THE MOST POPULAR VARIETIES OF LIMUS.

The three limus which are most popular and in the most general use by natives on all the islands are limu eleele, limu kohu (Pl. V), and limu lipoa. None of the other limus are so widely distributed on all the islands nor found in sufficient quantities to be in such general use and favor, except limu pahapaha and limu kala. Neither of these is popular with many Hawaiians, so they are used but little, even though abundant on all the islands.

Next in favor are limu manaua (Pl. VI, fig. 1), limu huna (Pl. VI, fig. 2), and limu pakaeleawaa (Pl. VII, fig. 1), though the latter is native only on the islands of Hawaii and Maui. It was transplanted by certain chiefs to a few places on Oahu and Molokai. The writer was unable to find any specimens of this limu on Kauai or Niihau when collecting on these islands during the summer of 1905, yet several natives insisted that it occurred in Kauai.

Limu luau is considered a great delicacy in the few localities where it occurs, but it lasts so short a season, is so scarce, and so difficult to get that it is not very widely known. Only on northern Kauai, northern Maui, and northern Hawaii is it in use or in great favor, as it does not occur in other places, except a few scattered plants on Molokai and Oahu.

METHODS OF PRESERVING SEaweEDS.

The Hawaiians usually preserve their seaweed, if only to be kept a few days or a week, by simply salting and tying closely in several layers of ti leaves and placing in a shady place. The ti leaves keep the seaweed from drying and also keep it crisp. The pounded seaweed is often stored in calabashes or glass jars after it is salted or put into weak brine.



LIMU KOHU (*ASPARAGOPSIS SANFORDIANA*).

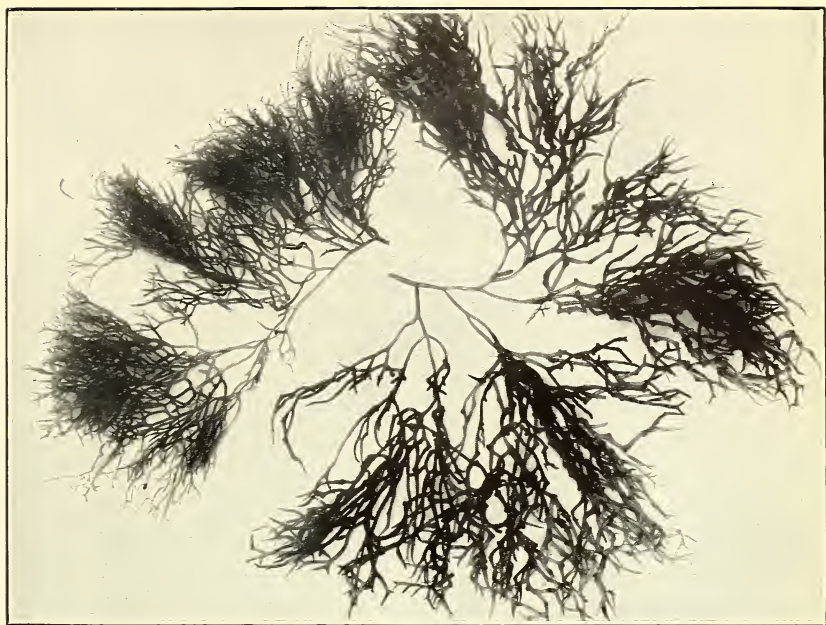


FIG. 1.—LIMU MANAUEA (*GRACILARIA CORONOPIFOLIA*).

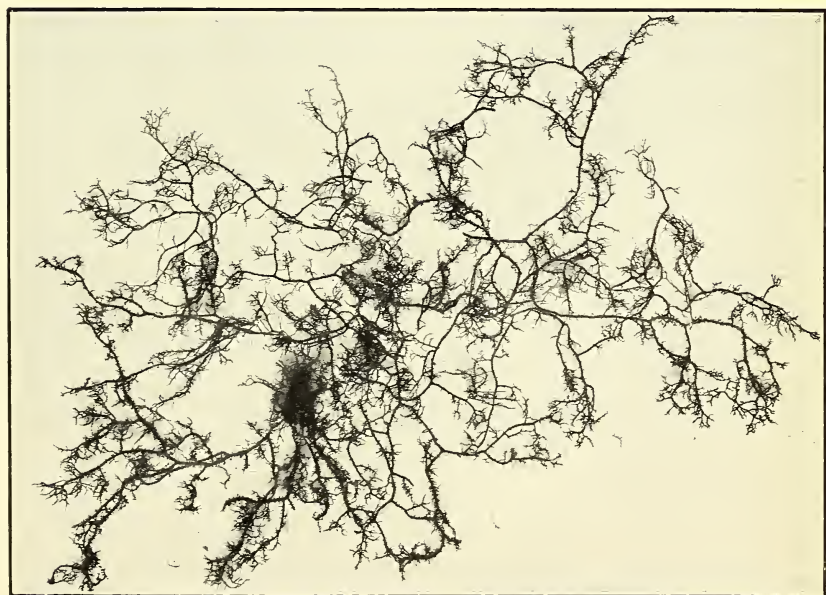


FIG. 2.—LIMU HUNA (*HYPNEA* SP.).



FIG. 1.—LIMU PAKAELEAWAA (*GRATELOUPIA FILICINA*).



FIG. 2.—LIMU AKIAKI (*AHNFELDTIA CONCINNA*).

Limu kohu, limu pakaeleawaa, limu liopa, and limu luau will keep many months, or even a year, when thus preserved. Limu lipoa is not usually kept very long, not more than a few weeks. Most all the other limus in common use are only kept from one or two days to a week, depending upon the weather and the locality. If limu is placed on ice it keeps considerably longer.

Limu pahapaha and limu pakaeleawaa are occasionally kept indefinitely by simply drying without washing off the sea water. Hawaiians very seldom use this method of preserving the limu, as they seem to think that it would be spoiled if allowed to dry. But few Hawaiians seem to know that almost all the seaweeds on the Hawaiian coast can be dried without any perceptible injury either to color, flavor, or texture. The writer has tried almost every species of Hawaiian seaweeds, and with two or three exceptions it was impossible to tell the dried specimens from the fresh if they were first soaked an hour or two in salt water. If fresh water is used for soaking or washing seaweeds it often removes the coloring matter either of the fresh or dried limu. Therefore it is best to add as much salt as is found in normal sea water when washing or preparing seaweeds, either for food or for specimens.

THE LIMUS MOST ABUNDANT AND EASILY GATHERED.

Perhaps the limus most abundant and widely distributed over all the islands are the various kinds of limu kala, and next, perhaps, are several kinds of limu pahapaha, which are found on all the islands and in considerable quantity. Limu huna and limu manaua are very abundant on the islands of Molokai, Oahu, and Kauai, and especially on the leeward side and where there are low shallow beaches and wide coral reefs. Limu huna is scarce on Maui and not reported from Hawaii at all and was not observed there by the writer when collecting. Limu manaua is less abundant on Hawaii and Maui than on the other islands. Limu akiaki occurs in large quantities on the submerged black lava of Kauai, Oahu, and Hawaii, but is plentiful in a few localities on the other islands. At one time it was tabooed except for the chiefs. Limu loloa is most abundant on the islands of Kauai, Molokai, and Oahu, but is found in considerable quantities on the other islands. Most of the limu uualoli is found chiefly on Maui and Molokai, but is rather scarce on Hawaii. Limu pakaeleawaa is only plentiful on the island of Hawaii on the southeast coast, but is found in limited quantities on Maui, Molokai, and Oahu, having been transplanted to the last two islands. Limu elele is found in large quantities in the brackish water at the mouth of all the streams that are not too swift.

All the limus mentioned above are easily gathered except limu uualoli, which grows on the stormy side of the islands on the most

exposed rocks, so unless the weather is very calm it is rather difficult to secure in large quantities.

Limu oolu grows in shallow water near shore or farther out on the shallow sand-covered reefs where the water is quiet, hence is quite easily gathered, but it occurs in rather limited quantity in but a few places.

All the other limus are more difficult to gather and also occur in more limited quantities and in but few localities. This is especially true of limu luau, which is extremely difficult to collect and is very scarce. It grows only on the most exposed and slippery rocks, and disappears in a few days after the stormy weather subsides not to reappear until the next season immediately after the heavy winds. Therefore this much-prized limu is always most difficult to obtain even in very small quantities.

Limu kohu, which is so eagerly sought, grows usually far out on the exposed rocks or on coral reefs, where the breakers dash, so is rather difficult to get even in quiet weather and impossible in heavy storms. Occasionally, however, it grows on reefs less exposed and more accessible.

Limu lipoa is limited to certain localities, and occurs in rather small quantities. It grows in rather deep water, so usually can be gathered only by diving or swimming. It is found in small quantities on all these islands, and is a general favorite.

Limu huna and limu manaua are often drifted upon the beach by the heavy winds or high tides, and may be very easily gathered in boat loads by wading along the shallows at low tide and gathering up the drift on the shore and at the water's edge. It is especially abundant where there are very wide coral reefs under shallow water and a sandy bottom. There are tons and tons of these two limus on the south coast of Molokai, south and east Kauai, and almost all around Oahu, except off Kaena Point and in the harbor, where the water is too deep or muddy for seaweeds to thrive. Wherever there are shallows or reefs off Maui it is also plentiful, though not in such large quantities as the other islands mentioned, because of a less favorable coast.

Limu manaua and limu huna are most abundant in early spring and during the summer months, though both are found in considerable quantities all the year, as would naturally be expected in a tropical region.

Limu loloa can be secured in large quantities all the year round on Molokai, Oahu, Kauai, and Maui, but is not so abundant on Hawaii. It grows on the great lava rocks exposed to waves, so in heavy storms it is difficult to secure.

Limu akiaki (Pl. VII, fig. 2) may be obtained by boat loads all the year, if not too stormy, as it also grows on the great black lava rocks

exposed usually to heavy surf. Sometimes it grows in quiet coves or behind the great lava rocks alongshore in less exposed places, but never in shallow water.

NATIVE METHODS OF CULTIVATING LIMU.

The writer was much surprised to learn that a rude kind of cultivation of the much-prized limu kohu was practiced at Moloaa, on Kauai. Here limu kohu grows very luxuriantly over the entire reef, and is the finest in color and flavor found on this group of islands.

There is a small cove just beyond Moloaa Bay to the northward, which is partly protected from the heavy trade winds and southerly storms by bold, rocky bluffs or headlands. The coral reef extends from the shore out perhaps a half mile and beyond the headlands, so that the whole cove has rather shallow water. The coral rock, the usual haunt of the limu kohu, is in this place somewhat protected from storms, so the natives can gather this limu almost any time of the year, when the tide is low, without danger from heavy breakers.

The Hawaiians living at Moloaa gather limu kohu for the Honolulu market regularly, making a nice little income from its sale, as they furnish the larger share of the supply. It is here that these limu gatherers have attempted to increase their sales by caring for their seaweed to the extent of weeding out all the other algæ, and thus, no doubt, increasing the quality and quantity of limu kohu, which here is so much finer and more luxuriant than in any other place. This is the only place of which the writer has heard where the limu is actually weeded and cared for as a garden. There are, however, several places where a certain favorite limu has been transplanted from other islands and guarded carefully until it could get established. Limu pakaeleawaa was transplanted from Hawaii to Molokai by an old chief, who planted it on the inner edge of his fish pond, where it is now growing luxuriantly. This same limu has also been transplanted to the beach in front of the residence of ex-Queen Liliuokalani, near Diamond Head, and also in front of her Waikiki place. It is thriving in both places, so the writer has been told. This last summer, when collecting on the north side of Oahu, in Kaneohe Bay, the writer was much surprised to find limu pakaeleawaa growing luxuriantly on the rocks near shore. The native fishermen said that it had been planted there many years before by a chief, who brought it from Hawaii. In all these instances there is an attempt to aid nature, and so a crude kind of limu culture is practiced in Hawaii, though, of course, it is not so extensive or systematic as that in Japan. There may have been more attempts at cultivating or transplanting seaweeds by the natives of the past, for no doubt when a chief moved from one island to another he brought with him his best taro and yam plants for his lands; why not his favorite limus to his fish ponds or beach?

VALUE AND AMOUNT OF NATIVE SEaweEDS SOLD IN HONOLULU.

It would be rather difficult to tell the exact amount or value of all the seaweed sold each year in Honolulu, but it is possible to make a fairly accurate estimate from the market inspector's report and the Chinese merchants' statements.

The inspector of the fish markets reports the annual sale of 4,800 pounds of limu, valued at about \$2,500. It is sold almost exclusively to the Hawaiians or part Hawaiians. Of this total about 2,000 pounds is limu kohu, which is worth about \$1,000 at retail. The remaining amount is about two-thirds to three-fourths limu eleele and limu oolu. All the rest are comparatively scarce or not so popular, so are only in the market occasionally during certain seasons of the year. Limu kohu is always in the market, while the other limus are usually found only on Saturdays and the day before holidays.

The following limus are found in the Honolulu fish market, either regularly or at intervals, according to the season or the weather: Limu kohu (*Asparagopsis sanfordiana*), limu eleele (*Enteromorpha prolifera*, *E. flexuosa*, *E. intestinalis*, *E. hopkirkii*, and *E. plumosa*), limu oolu (*Chondria tenuissima*), limu lipeepee or limu maneoneo (*Laurencia papillosa*, *L. pinnatifida*, *L. virgata*, *L. obtusata*), limu manauca (*Gracilaria coronopifolia*), limu lipoa (*Dictyota acutiloba* and *Haliseris plagiogramma*), limu kalawai (*Naias major*), and occasionally limu huna.

Usually these native limus are cleaned, pounded, and salted all ready for serving before they are offered for sale in small plates or saucers. These plates contain from a half pound to a pound of the limu, which sells at from 5 to 25 cents per plate, depending upon the kind. A few varieties like limu lipoa, limu lipeepee, limu manauca, limu huna, and limu kalawai, or fresh-water kala, are sold in loose handfuls, with no preparation except washing off the sand. Every native who buys a fish or a lobster also buys his plate or handful of limu.

Limu kohu is always pounded fine enough to be pressed into balls before it is packed with salt in tins or barrels to be shipped to Honolulu market. When retailed it is made into balls about the size of a large baseball and weighing about a pound. They always sell at 25 cents each, though the balls are smaller in stormy weather when limu kohu is scarce. All these limus are very moist, so they are always tied up neatly in fresh green ti leaves when purchased to prevent the water from leaking out upon the buyer's clothes. The ti leaves also keep the limu fresh and moist and never soak up the water as paper does if tied about something wet.

Nearly all the limu is sold in the market by native women, who have other Hawaiian delicacies, as sea urchins, roasted kukui nuts, crabs, cocoanut pudding, small cubes of raw beef liver, ready to serve with limu, etc.

The amount of limu sold in Honolulu does not of course include nearly all that is actually consumed either on these islands, on Oahu, or even

in Honolulu, as every native family living on or near the beach gets its own supply of algæ fresh from the sea whenever it is desired.

VALUE OF SEAWEEDS IMPORTED BY ORIENTALS INTO HAWAII.

The Japanese and the Chinese of Hawaii use a large quantity of seaweed of various kinds, either prepared in various ways or simply roughly dried. The Orientals seldom use the Hawaiian algæ, as they prefer that cured and prepared in their own country. This is sold only in the Chinese or the Japanese grocery shops.

Most of this imported seaweed comes from Japan and is either kombu or wakame and its various preparations. The Japanese consular report for 1904 says the amount of seaweed sold to Hawaii and to the United States was as follows:

Japanese seaweed sold to Hawaii and the United States, 1904.

Seaweed from Japan.	Weight.	Value.
	<i>Pounds.</i>	
Rough-dried algæ sold to Hawaiian Islands.....	112,492.73	\$1,587.15
Cut or prepared algæ sold to Hawaiian Islands.....	40,789.77	876.14
Algæ isinglass or kanten sold to Hawaiian Islands.....	1,751.61	470.72
Algæ isinglass or kanten sold to United States.....	61,558.31	15,152.30
Total	216,622.42	18,086.31

Nearly all the seaweed preparations described by Hugh M. Smith in his Report of the Japanese Seaweed Industry are sold here in Honolulu by the Japanese grocers to our Japanese population. The different seaweeds and their preparations vary in price from 5 to 30 cents per pound retail. The kanten costs about \$1.50 or \$1.65 per pound, and it is extremely light for its bulk. Amanori sells in small, thin sheets about 5 by 12 inches for 10 cents per dozen sheets. These sheets are almost as light as paper. Kombu and wakame are sold in the largest quantities, and are boiled to serve with rice, fish, and vegetables.

The Chinese import large quantities of seaweed each year, but there are no consular reports that give the amount or its value; so the following figures are taken from various estimates made by intelligent and responsible Chinese merchants who import this commodity. There are probably 70,000 to 80,000 pounds of seaweed, valued at from \$10,000 to \$12,000, imported and sold annually by the Chinese grocers of Honolulu.

The prices of these Chinese seaweeds vary from 10 or 15 cents per pound retail for che choy or kum choy (*Porphyra perforata* and *P. nereocystis*), 7 to 35 cents per pound for toi choy, hoy tai, and san choy (all *Laminaria* sp.), and 75 cents to \$1.50 per pound for fat choy (*Xostoc commune flagelliforme*).

The most expensive varieties of seaweed are not sold in large quantities, and of course are purchased only by the most prosperous class of Chinese for feasts and holidays. Fat choy is used in very small quantities, as it is extremely light, swelling greatly in water when

soaked or cooked, so that an ounce makes a considerable bulk when ready to serve. This is also true of most dried seaweeds, and especially of the common kombu, wakame, and che choy.

Che choy (*Porphyra perforata*) is imported from San Francisco and is a substitute for a Chinese alga called tsu choy (probably *Porphyra orbiculata* and *P. tenera*) which is greatly prized by the Chinese. It costs from 75 cents to \$1 per pound when imported from China and keeps very poorly, often spoiling soon after its arrival: hence the use of the cheaper che choy from San Francisco. This retails here at 12 to 15 cents per pound, and is said to be almost as good as the Chinese variety. The tsu choy is imported only in small packages for the New Year feasts and sold to a few Chinese epicures.

One Chinese wholesale grocer said that he imported annually two or three tons of che choy, which costs from \$600 to \$700. He estimated that from 25 to 30 tons of this seaweed was imported yearly from San Francisco, costing from \$6,000 to \$7,000.

The Chinese use seaweed very much in the same way as the Hawaiians. They cook it in soups, stewed meats, or gravy, and also make it into pickles, preserves, or candies and other sweetmeats.

USE OF LIMU FOR MEDICINE AND INCANTATIONS.

The writer has been unable to gather much data regarding the medicinal uses of limu, yet the few items collected are of considerable interest. Certain green fresh-water algæ, species of *Spirogyra* and *Cladophora*, are said to heal sore eyes if tied on as a poultice. Limu kala is pounded with salt and bound about bruises and cuts to relieve pain. Limu huna is sometimes boiled and the hot infusion given for stomach ache. Limu eleele is dried and put on boils, or it is sometimes used fresh and moist to poultice boils. Limu pahapaha is pounded and put on bruises. Lima luau is pounded to a pulp with salt and the juice is used to moisten bandages on cuts or bruises. Limu eleele and limu palawai are both pounded with salt and tied on cuts and bruises. Limu maneoneo is pounded with salt and the juice is put on cuts or bruises. A species of *Centroceras*, probably *C. clavulatum*, is pounded with salt and put on bruises and sores. An infusion of this same alga, when cooked, is given for a cathartic.

Limu kala is used by the kahunas or witch doctors in incantations to drive away sickness. The superstitious native when ill gathers limu kala, makes a lei for head or neck, eats some, says a prayer of penitence, promises to do better, then goes into the sea. He must not look back, speak, or beckon to anyone until he takes the limu lei, places it on head or neck, eats a bite of it, then throws the lei back into the sea, still looking out to sea and praying for forgiveness. This ceremony is said to cure if it is faithfully carried out.

It is believed that a most effective love potion is made from limu kalawai, or fresh-water limu kala as it is often called. The lovelorn

maiden says over a magic spell learned from a kahuna, eats the limu kala, then gives some to the one whose love is desired. Straightway he adores her. Limu awikiwiki (*Gymnogongrus vermicularis*) was used also in love-making charms in ancient days, and was probably equally effective.

CHEMICAL ANALYSES AND COMPARATIVE FOOD VALUES OF SEAWEEDS.

The algæ when gathered are very succulent and contain a large amount of water. Considerable of this moisture is lost in the various methods of preparation for the table or for other uses. A number of specimens of Hawaiian algæ were analyzed by Mr. R. A. Duncan, food chemist of Hawaii, in connection with the writer's investigation of this class of plants, and the results are given in the table below, together with some similar analyses which have appeared in earlier publications of the Office of Experiment Stations and elsewhere. All the samples analyzed were air dry.

Composition of edible algæ.

[Air-dry material.]

	Water.	Protein.	Fat.	Carbohydrates.		Ash.
				Sugar, starch, etc. ^a	Crude fiber.	
	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>
Irish moss (<i>Chondrus crispus</i>) ^b	18.8	9.4	.....	55.4	2.2	14.2
Fat choy (<i>Nostoc commune flagelliforme</i>) ^c	10.58	20.93	1.19	55.73	4.07	7.50
Amanori or che choy (<i>Porphyra laciniata</i> or <i>vulgaris</i>) ^c	21.85	25.70	.17	37.68		14.60
Do. <i>d</i>	15.48	34.35	.65	38.83		10.69
Do. <i>d</i>	20.42	36.26	1.21	33.28		8.83
Do. <i>d</i>	16.40	35.63	.50	38.13		9.34
Do. <i>d</i>	14.58	32.44	.70	43.28		9.00
Do. <i>e</i>	13.98	33.75	1.30	41.22		9.75
Kombu or kelp (<i>Laminaria angustata</i>) ^f	22.82	5.49	1.52	46.93	4.55	18.69
Kombu or kelp (<i>Laminaria longissima</i>) ^f	25.94	6.72	1.73	31.90	6.42	27.29
Kombu or kelp (<i>Laminaria japonica</i>) ^f	22.97	4.96	1.59	47.49	5.83	17.16
Kombu or kelp (<i>Laminaria ochotensis</i>) ^f	23.99	6.65	.86	42.16	6.03	20.31
Kombu or kelp (<i>Laminaria religiosa</i>) ^f	22.75	4.72	.82	42.88	10.20	18.63
Kombu or kelp (<i>Laminaria fragilis</i>) ^f	23.10	4.03	.65	40.41	7.15	24.66
Kombu or kelp (<i>Laminaria</i> sp.) ^e	23.08	7.11	.87	47.70		21.24
Kombu or kelp (<i>Arthrothamnus bifidus</i>) ^f	24.43	5.82	.74	45.58	6.44	16.99
Kanten or seaweed gelatin ^g	22.80	11.71	.....	62.05	.....	3.44
Do. <i>h</i>	22.29	6.85	.....	60.32	6.73	3.81
Awo-nori (<i>Enteromorpha compressa</i>) ⁱ	13.60	12.41	52.99		10.58	10.42
Awo-nori (<i>Enteromorpha linza</i>) ^e	13.53	19.35	1.73	46.18		19.21
Limu akiaki (<i>Ahnfeldtia concinna</i>) ^j	20.16	5.60	.07	54.96	2.66	16.55
Limu pahapaha (<i>Ulva fasciata</i> and <i>U. lactuca</i>) ^j	18.68	14.87	.04	50.65	.19	15.57
Limu manauca (<i>Gracilaria coronopifolia</i>) ^j	12.87	7.91	.05	58.41	2.98	17.78
Arame (<i>Ecklonia bicyclis</i>) ^k	13.17	8.99	.....	45.70	7.40	24.74
Do. <i>e</i>	18.75	9.58	.46	51.63	9.79	9.79
Hijiki (<i>Cystophyllum fusiforme</i>) ^k	16.40	8.42	.....	41.92	17.06	16.20
Do. <i>e</i>	15.74	11.37	.49	54.84		17.56
<i>Ulopteryx pinnatifida</i> <i>e</i>	18.92	11.61	.31	37.81		31.35
<i>Ecklonia bicyclis</i> , partially dried ^l	55.62	4.96	.40	13.60	19.16	6.26
<i>Laminaria</i> , partially dried ^l	52.96	4.11	1.44	29.68	5.25	6.56
Do. <i>l</i>	68.26	2.80	.48	19.50	3.29	5.67

^a Computed by difference except in a few cases which were actually determined.

^b United States Dispensatory.

^c U. S. Dept. Agr., Office of Experiment Stations Bul. 68, p. 47.

^d Imperial Fisheries Bureau of Japan, quoted in Bul. [U. S.] Bureau Fisheries, 24 (1904), p. 160.

^e Tahara, quoted in U. S. Dept. Agr., Office of Experiment Stations Bul. 159, p. 40.

^f K. Oshima, quoted in Bul. [U. S.] Bureau Fisheries, 24 (1904), p. 153.

^g O. Kellner, quoted in Bul. [U. S.] Bureau Fisheries, 24 (1904), p. 141.

^h Imperial Fisheries Bureau of Japan, quoted in Bul. [U. S.] Bureau Fisheries, 24 (1904), p. 141.

ⁱ O. Kellner, quoted in Bul. [U. S.] Bureau Fisheries, 24 (1904), p. 164.

^j R. A. Duncan, food chemist for the Territory of Hawaii.

^k E. Kinch, quoted in Bul. [U. S.] Bureau Fisheries, 24 (1904), p. 163.

^l Murai and Kasama, quoted in U. S. Dept. Agr., Office of Experiment Stations Bul. 159, p. 43.

For a proper comparison the fresh algæ should be compared with succulent green foods, like spinach and bananas, or such materials as poi or taro. If the air-dry materials are considered they should be compared with such articles as dried vegetables, crackers, meal, beans, cheese, dried beef, dried fish, etc. In the following table analyses are given of a number of common articles of food, and for comparison three of the more common limus are included, which have been calculated on a uniform water basis of 80 per cent:

Composition of marine algæ compared with other foods.

	Water.	Protein.	Fat.	Carbohy- drates.	Ash.	Fuel value per pound.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Calories.</i>
Limu akiaki (<i>Almofeldtia concinna</i>) ^a	80.0	1.4	0.0	14.4	4.2	290
Limu pahapaha (<i>Ulva fasciata</i> and <i>U.</i> <i>lactuca</i>) ^a	80.0	3.7	.0	12.5	3.8	295
Limu manaua (<i>Gracilaria coronopi- folia</i>) ^a	80.0	1.8	.0	14.1	4.1	290
Wheat bread ^b	35.3	9.2	1.3	53.1	1.1	1,185
Corn meal ^b	12.5	9.2	1.9	75.4	1.0	1,610
Crackers ^c	6.8	10.7	8.8	71.9	1.8	1,905
Taro ^d	67.5	1.9	.2	29.3	1.1	595
Poi ^d	83.0	.3	.6	15.8	.3	325
Potatoes ^c	78.3	2.2	.1	18.4	1.0	385
Sweet potatoes ^c	69.0	1.8	.7	27.4	1.1	570
Beans, Lima, shelled ^b	68.5	7.1	.7	22.0	1.7	555
Beans, dried ^b	12.6	22.5	1.8	59.6	3.5	1,560
Bananas ^c	75.3	1.3	.6	22.0	.8	460
Spinach ^b	92.3	2.1	.3	3.2	2.1	110
Beef, round ^c	67.8	20.9	10.6	.....	1.1	835
Pork, shoulder ^c	51.2	13.3	34.2	.....	.8	1,690
Codfish, salt ^c	53.5	25.4	.3	.....	24.7	410
Beef, dried, salted, and smoked ^c	54.3	30.0	6.5	.4	9.1	840
Mullet ^c	74.9	19.5	4.6	.....	1.2	555
Eggs, hen's ^c	73.7	13.4	10.5	.....	1.0	720
Cheese, full cream ^b	34.2	25.9	33.7	2.4	3.8	1,875
Rice ^b	12.3	8.0	.3	79.0	.4	1,590

^a Recalculated from figures given in preceding table to uniform water content.

^b U. S. Dept. Agr., Office of Experiment Stations Circ. 46 (revised).

^c U. S. Dept. Agr., Office of Experiment Stations Bul. 28 (revised).

^d E. C. Shorey, Hawaii Experiment Station.

As will be seen by the data in the above tables, carbohydrates constitute the principal nutritive material present in algæ, though they contain considerable quantities of protein and relatively high proportions of ash. So far as can be learned little information is available regarding the character of the nitrogenous material present and the proportions of albumins, which have a high food value as compared with amids or other nitrogenous extractives. As a class the algæ differ very decidedly from the usual food materials in the character of the carbohydrates present, starch being usually replaced by such carbohydrates as mannit and substances which yield on hydrolysis various galactoses, mannose, glucose, pentose, etc.^a

Judged by chemical composition the air-dry algæ compare favorably with other common food materials, particularly those of vegetable

^a See summary of data in U. S. Dept. Agr., Office of Experiment Stations Bul. 159, p. 34.

origin. It has been commonly supposed that the Irish moss, so much used in invalid dietetics, and other algæ and food made from them were very thoroughly assimilated, but recent experiments carried on by T. Saiki, at Sheffield Scientific School, Yale University, indicate that this is not the case, at least with respect to the carbohydrate constituents. That they are wholesome and are palatable additions to the diet in regions where they are eaten in quantity is well established, and it seems fair to say that they occupy much the same place in the diet as other common foods, particularly green vegetables. In order that digestion should be normally accomplished foods should be bulky, and in this respect the marine algæ would certainly prove useful. Mineral matters are needed for the formation of bones, teeth, and other tissues, and to fulfill other physiological functions. The algæ are rich in phosphates, chlorids, bromids, iodids, etc., and it seems probable that the mineral matter which they supply must be of importance to the body. As Saiki points out, the algæ gelatins are of much importance in counteracting constipation.

AMOUNT OF GELATIN OR GLUE FOUND IN HAWAIIAN ALGÆ.

The writer made some rather crude experiments to test the various common limus of Hawaii for the amount of gelatin available by ordinary boiling. The most satisfactory results were obtained from the following varieties: *Limu huna*, *limu manaua*, *limu akiaki*, *limu kohu*, *limu loloa*, and *limu pakaeleawaa*. Some others were tried, but they contained very little gelatin or were too strong in flavor to make gelatin for foods. The *limu loloa* made a very dark gelatin, with a rather strong flavor, so would be more valuable for making mucilage than for gelatin. In making these experiments to extract the gelatin only a small coal-oil stove and a few tin pails were available for boiling the algæ. The seaweed was carefully washed and cleaned, then boiled in clear water from 1 to 3 hours. When it seemed well softened or dissolved, it was passed through a coffee strainer, then through coarse linen doubled. It came through clear, and soon stiffened on exposure to the wind and sun. It was all dried in clear, stiff, crisp sheets on plates in a sunny window. It looked as clear and fine in quality as the best gelatins of the market.

The time of cooking, the amount of gelatin obtained, as well as the quality, varied with the kind of seaweed used. *Limu manaua* makes the finest, clearest gelatin, and *limu akiaki* ranks next, *limu huna* third in quality, while *limu pakaeleawaa* makes the poorest and smallest quantity. *Limu manaua* requires the least cooking, and *limu huna* is next, while *limu loloa* makes the darkest colored and strongest flavored gelatin. It would make an excellent glue, because it is very sticky, but dries hard as glue should.

Roughly estimated, these seaweeds yield 75 to 80 per cent of their dry weight of gelatin or glue. The writer had no means of carefully weighing the materials to get the exact proportions of seaweed and the glue or gelatin obtained in order to make accurate estimates of their ratios. All the seaweeds occurring on Hawaii in large quantities were tested for gelatin with the above results. Limu uualoli probably contains a considerable amount of gelatin, but is difficult to gather and can only be secured with some difficulty, and only in very moderate quantities on the north side of Maui, Molokai, Oahu, and Kauai. It is possible that some of the species of *Laurencia* as limu lipeepee and limu maneoneo might yield some gelatin, but they do not occur in large enough quantities to be of importance in this consideration.

The writer tried using some of this seaweed gelatin as mucilage for pasting on labels and pictures, etc., and found it just as satisfactory as ordinary library paste. It left no shiny mark on the edges. If kept from fermenting by some preservative it would undoubtedly be just as useful as any other mucilage.

HAWAIIAN LIMUS FOR MAKING AGAR AGAR FOR CULTURE MEDIA.

Two small jars of the clearest, best gelatin made from limu manauaea and limu huna were taken to the laboratory of Dr. N. A. Cobb, plant pathologist at the Hawaiian Sugar Planters' Experiment Station, to be tested as culture media. He reported them to be quite satisfactory for cultures of various fungus diseases. No doubt if this gelatin were mixed with beef tea, milk, or other suitable foods it would make just as satisfactory a medium for the culture of the bacteria. If we could produce our own agar agar in the United States it would of course save importing it from abroad. Most of the agar agar used in the laboratories of the United States and Europe is made from the algæ of Japan and Ceylon or Java. It is prepared partly in Japan, but the best quality is sent to Germany to be manufactured. We have tons of gelatinous algæ here in Hawaii that would make the best quality of agar agar if we chose to manufacture it ready for the bacteriologist.

FURTHER UTILIZATION OF HAWAIIAN SEaweeds FOR FOOD, GELATIN, FARINA, GLUE, AND MUCILAGE.

It is not probable that raw seaweed prepared in the usual Hawaiian style would ever be generally popular with the American or European, who naturally prefers his own salads and relishes to which he is accustomed. Even those having the most pleasant saline flavor and crispness, as limu kohu, limu manauaea, limu huna, and limu pahapaha, or limu lipoa, with its peculiar pleasant spiciness have in addition a slight flavor that suggests the sea, to which many people object. It is only

after tasting several times that many people come to really like the marine flavor, common to all raw seaweeds. All the others that the writer has tasted, except those mentioned above, have a much stronger flavor, which is sometimes slightly bitter or suggests iodine, or, again, it is slightly fishy, so that it would not appeal to the average American palate.

Many of the seaweeds, when cooked in soups, gravies, or with meats or made into jellies, are entirely free from this disagreeable or peculiar flavor. If cooked too long, or too large a quantity is used in the soups or jellies, the flavor is apt to be strong, but if used in smaller quantities it is very delicate and pleasant. The writer has carefully tested a number of species, cooking them in a variety of combinations. They seem to be equally palatable when used either fresh or dried. The bleached seaweeds of course make the best appearing jelly and blancmange, and look best in the soups and stews.

The most attractive and delicately flavored coffee, fruit, or other jellies and blancmange was made by the writer from the four gelatinous limus mentioned above. They were equal in every way to jellies made from the best gelatins in the market, and in some ways seemed superior in flavor. The blancmange could not be distinguished from that made with Irish moss farina or with the whole Irish moss.

No doubt these native limus which occur in large quantities could be collected and bleached on the sand or rocks by the natives, and when dry and clean ground into farina or made into gelatin as good as any in the market. The farina made from limu huna, limu manaua, limu akiaki, and limu pakaeleawaa would be excellent for thickening soups, stews, and gravies or puddings in the same way as tapioca, sago, or Irish moss farina. When once the public became acquainted with these preparations without doubt they would become popular. A careful, experienced manufacturer might, it would seem, start a new industry here in Hawaii or on the California coast by utilizing the tons and tons of edible and gelatinous algæ in making gelatin or glue, such as that made in Japan, or farina, as on the coast of New England. There is no reason why Hawaiian species could not be made into as good gelatin and glue as the Japanese or Ceylon algæ. If scientific methods were used in its preparation, and labor was reasonable, we ought to be able to make our algæ as profitable as that of Japan. The many poor Hawaiians living along the beaches, who have no fertile land to cultivate and are only skilled in fishing, swimming, and rowing, could engage in collecting algæ for such a factory. The women and children could help in this industry and all could stay at home together. They would need no tools and no capital or no training for this work. A few simple instructions about cleaning, drying, and bleaching would be sufficient, for the natives know the haunt of every edible limu. A very cheap mill would do for grind-

ing the limu into meal or farina, which would need to be boxed and labeled attractively. The gelatin factory would require more machinery and more capital. It may be that if no factory should be started here our Hawaiians might collect, dry, and bleach their limus and ship them to the coast in bags ready to manufacture, and still make it a profitable industry.

METHODS OF PREPARING JELLIES, BLANCMANGE, SOUPS, ETC.

Coffee jelly and other similar jellies or gelatin desserts are prepared in the same manner as when ordinary gelatin is used, except that the gelatin must first be extracted from the algæ as described above in gelatin preparations. The clear, strained gelatin is then sweetened and flavored with fruit juice, coffee, etc., and placed in a mold to stiffen. It is then served with sweetened and flavored cream, just as with all gelatin jellies. The amount of dried seaweed needed for a pint of jelly varies from 1 to 4 ounces, depending upon the variety of algæ and the stiffness desired in the jelly. The time of cooking also varies with the algæ, and is from one to two hours.

Blancmange is made just as with Irish moss, by cooking the algæ slowly in sweet milk and then straining through a bag. After it is sweetened it is placed in the mold on ice to cool and served with cream sweetened and flavored to taste.

The same limus used in making gelatin are of course used for jellies, blancmange, and in meats and soups. Limu manaua makes the most delicately flavored desserts, though limu huna, limu akiaki, and limu pakaeleawaa are almost as good. Limu kohu is also a pleasant addition to soups or stews if used sparingly, an ounce or two to a kettleful of soup.

COMPARISON OF HAWAIIAN AND JAPANESE SPECIES OF ECONOMIC ALGÆ.

Though Hawaii is a group of recent volcanic islands in mid-ocean, it has a rather varied marine flora along the coasts. There are a hundred and ten or fifteen different species found on these islands. About seventy of these are used for food by some of the Hawaiians. From forty-five to fifty species are in general use for food by most of the Hawaiians on the different islands where they grow.

Japan, being composed of older continental islands, would naturally be expected to have a richer seaweed flora (and probably it has), but Mr. Smith^a reports a much smaller number of edible seaweeds from those islands than we have in Hawaii. He reports but 35 species that are eaten by the Japanese and 10 others valuable for making glue, gelatin, iodine, fertilizers, etc.

^a H. M. Smith, Seaweed Industries of Japan. Bul. [U. S.] Bureau of Fisheries, 24 (1904).

Not all of these 70 seaweeds eaten by the Hawaiians would be agreeable to the palate of the average American. Probably not more than 8 or 10 out of the 70 would be eaten either by the American or the European, and some of these 10 only occur in limited quantity and only in a few localities. There may, of course, be a few seaweeds here in Hawaii that will prove to be valuable for fertilizers, iodine, or gelatin that have not yet been tested, as the Sargassums.

Probably none of our Hawaiian seaweeds occur in such large quantities as those in Japan, since our coast is much less extensive and many of our islands have bold, precipitous coasts, with very deep water coming up close to the shore on one or two sides. Algæ grow most abundantly in the shallower waters near the coast, and hence the more coral reefs and the more extensive shallows the greater variety and quantity of seaweed. It is, of course, more easily collected on shallow rocky coasts or in coves and bays protected by wide coral reefs, while it is always most plentiful on the coral rocks in these shallows. The tougher, more leathery varieties thrive in the more exposed places and find secure anchorage on the black lava rocks or basalt, as well as on the softer vesiculate lava, which is usually covered with algæ of various kinds, different from that growing on the coral.

While Hawaii is within the tropic zone and probably considerably warmer than Japan, yet she has some of the same species of economic algæ that grow on her coasts. Hawaii produces eight or nine species of *Gelidium*, while one is the same species (*Gelidium corneum*) which is found so abundantly in Japan and is used in the manufacture of seaweed gelatin. Our species of *Gelidium* are undoubtedly as gelatinous as the Japanese species, but they are not nearly so plentiful. We also have *Gracilaria confervoides* and *G. coronopifolia*, which are very common on the coasts of Japan. *Gracilaria coronopifolia* is particularly rich in gelatin of the best quality suitable for food, and it also occurs in considerable quantities on all the islands but Hawaii. Our *P. leucosticta* is somewhat similar to the two *Porphyras* of Japan used in making amanori, but is too rare and too difficult to collect to be of any economic importance here on Hawaii. We also have two edible species of *Codium*, while Japan has three edible species, but different from ours. Our edible *Grateloupia filicina* is the same as the one used in Japan, though they have two other edible species of *Grateloupia*. We have two of the three Japanese species of *Enteromorpha*, besides three or four more edible species. There are two edible species of *Gymnogongrus* reported from Japan, and we have the same number here, though different species. Of our three edible *Ulvas*, one is the same, one a variety, and the other is a nearly related species to those found in Japan. We have three or four species of edible

Sargassum, while Japan has only one species of Sargassum, which is used for making iodin.

The Japanese waters are rich in kelps, laminarias, alaria, ecklonia, and other genera of colder waters, but Hawaii has none, nor has she any Chondrus or Gloiopeltis, both of which thrive best in the North Pacific along the coasts of Japan and the United States. The kombu and wakome preparations of Japan are all made from Laminaria and related genera in the kelp group.

It will be seen from the above comparison of genera and species that there is some resemblance between the seaweeds of Japan and Hawaii. Our waters being warmer we naturally have more tropical species and no kelps. Yet quite a number of genera and several species are exactly the same. This would indicate either that these species flourish under widely different temperatures and conditions, or that our water is not so much warmer as the difference of latitude would suggest. Japan has the volcanic rock and the black lava just as we have here, but probably no coral reefs for the algæ.

POSSIBILITY OF CULTIVATING NATIVE, JAPANESE, JAVA, OR CEYLON ALGÆ IN FAVORABLE LOCALITIES ON THE HAWAIIAN OR AMERICAN COAST.

As previously mentioned, the Hawaiians have attempted a rude method of cultivating and transplanting their favorite algæ from one island to another. In moving from island to island the chiefs carried their favorite limu pakaaleawaa from Hawaii to Oahu and to Molokai. It was transplanted carefully along protected beaches or on the inner side of old fish ponds, where it still thrives. The writer found this alga growing only in one place on Molokai, and was told by the natives that it had been planted by a chief in his fish pond. In the same manner it has been planted on Oahu in several places and is thriving. Limu is weeded and cared for on the island of Kauai in order to increase the quantity and quality.

If these crude methods of culture succeed and the natives can establish an alga in a new place successfully, why should not more careful scientific means be very successful if the most desirable varieties of Hawaiian algæ were planted in the most favorable localities on each island?

Perhaps some of the most valuable Japanese algæ could be introduced on the coast of Hawaii and be successfully established. It is possible, too, that certain species of algæ growing on the coasts of Ceylon and Java could also be just as readily transplanted to our islands, because the temperature of the sea is about the same, especially off the coast of Hawaii. Much of the agar-agar of commerce is prepared from the gelatin obtained from seaweeds from Java and Ceylon. This very important requirement of every bacteriological laboratory

might be produced here in Hawaii just as well as in Japan or the East Indies, providing, of course, that our own algæ proves as rich in gelatin or if the Japanese and East Indian seaweeds can be successfully introduced and cultivated here. Some experiments along this line might be very valuable, and they would certainly be very interesting. There are many of our rocks and reefs quite thinly covered or nearly barren of seaweeds, and these might be favorable places to establish new varieties, either from other islands or from Japan and the East Indies.

GENERAL SUMMARY OF THE POSSIBILITIES OF THE SEAWEED INDUSTRY.

If the seaweed industry of Japan is the source of an annual income of \$2,000,000, it seems possible that our edible Hawaiian algæ might be available for building up a similar industry of considerable value. The coast line of Hawaii is much less extensive and the amount of seaweed of course very much less, yet there is enough material to supply large factories for making gelatin, glue, farina, or other products. If in addition to the present natural sources of seaweed new localities be successfully planted, either with native, Japanese, or other valuable foreign varieties, a still larger supply of algæ would be available for manufacturing. It would of course take some capital, business judgment, and knowledge of the seaweeds and their manufacture to successfully establish such an industry here or on the coast of the United States. If it is so profitable in Japan, why should it not be profitable here, if properly handled? There are enough Japanese laborers here who know all the methods of preparing algæ to suit the Oriental palate, and these could be employed to do that part of the work in the factory, while the Hawaiians, who love the water and are such expert swimmers and boatmen, could be employed to collect the crude algæ from the sea and bring it to the factory. This would bring employment to the untrained Hawaiians and furnish them with a means of living while they remained at home. The women and children could also help with this work of gathering and drying or bleaching the seaweed for the manufacturer. Some industry of this kind only will bring relief to the mass of the Hawaiians, who are unskilled and undisciplined, so are unable to compete with either the Orientals or Europeans in any branch of labor. The Japanese have driven them out of fishing, at which they are most skillful, because they will not be strenuous or regular enough to furnish the market with fish. Small farming is not practicable for the Hawaiian under present conditions, because it requires more capital, skill, and intelligence than the present Hawaiian possesses. Perhaps in two or three more generations the Hawaiian will acquire the skill, the capital, and the disposition to enter agricultural pursuits gladly. In the meantime poverty and distress are the lot of a large class of landless Hawaiians

living along our coast. If the tons of algæ wasting on our shores could be utilized for gelatin, glue, farina, etc., it would bring some relief to this class, as well as add to the general wealth and prosperity of these islands and to the United States.

The gelatins and glues imported from Japan could be made in the United States just as cheaply, perhaps. Modern methods scientifically applied and machinery would reduce the manufacturing expenses to a minimum. A new source of food for our American people here and in the United States would add also to our national wealth. Further experiments and analyses should be made by the Government to test the nutritive value of our algæ and to find the best methods of securing the greatest amount of gelatin from each variety. Enough has already been done to suggest the future value of our economic algæ if properly utilized.

List of edible algæ of Hawaiian Islands.

Scientific names.	Native names.
<i>Almfeldtia concinna</i> J. Agh.	Limu akiaki, or limus eleau. ^a
<i>Asparagopsis sanfordiana</i> Harv.	Limu kohu, limu lipaakai, ^b limu lipehu, limu koko.
<i>Amansia glomerata</i> Ag.	Limu lipepeiao, ^c or limu pepeiao.
<i>Centroceras clavulatum</i> (Agh.), Mont.	Limu huluilio, limu hulu, or limu hulu wawae-iole.
<i>Chatomorpha antennina</i> (Bory.), Kuetz.	Limu huluilio, ^d limu ilio, or limu manu.
<i>Champia compressa</i> , Harv.	Limu oolu.
<i>Chnoospora fastigata pacifica</i> , J. Ag.	Limu wawahiwaa, or limu kaupau.
<i>Chondria tenuissima intermedia</i>	Limu oolu.
<i>Chylocladia rigens</i> ?	Limu akuila, or limu kihe.
<i>Cladophora nitida</i> , Kuetz.	Limu huluilio.
<i>Codium muelleri</i> , Kuetzing.	Limu aallaula, ^e limu wawaeiole, or limu wawaimoa.
<i>Codium adhaerens</i> (Cabr.), Agh.	Limu aalaula.
<i>Codium tomentosum</i> (Huds.), Stackh.	Do.
<i>Dictyota acutiloba distorta</i>	Limu alani, ^f or false lipoa.
<i>Dictyota dichotoma</i>	Do.
<i>Ectocarpus indicus</i> ?	Limu akaakoa, or limu huluilio.
<i>Ectocarpus</i> sp.?	Do.
<i>Enteromorpha flexuosa</i> (Wulf.), Ag.	Limu eleele, or limu pipilani. ^g

^a Many of the limus have different local names, or each island or adjoining islands has its own name. Limu eleau is used on Maui only.

^b This limu is usually called limu kohu, except on Maui, Molokai, and Kauai. It is often called limu lipaakai and sometimes limu lipehu. Limu koko is a corruption of kohu.

^c Different forms of the same name on Hawaii, not widely used, local.

^d Not widely used; only local on several islands, chiefly on Hawaii and Maui, and this name is applied to several species slightly resembling each other. It means dog's hair.

^e The last two names found in use in some places on Hawaii, not common.

^f This is generally called limu alani, but sometimes called false limu lipoa, which it resembles slightly. It is eaten but seldom, as it is bitter.

^g On Maui it is sometimes called limu pipilani. Limu eleele is the name for most all the *Enteromorphas* of these islands.

Scientific names.	Native names.
<i>Enteromorpha hopkirkii</i>	Limu eleele, or limu pipilani. ^a
<i>Enteromorpha intestinalis</i> (L.), Link.	Do.
<i>Enteromorpha linza</i> (L.), J. Ag.	Do.
<i>Enteromorpha plumosa</i> , Kuetzing	Do.
<i>Enteromorpha prolifera tubulosa</i> , Kg.	Do.
<i>Enteromorpha prolifera</i> (Muell.), J. Ag.	Do.
<i>Gelidium attenuatum</i> ?	Limu loloa.
<i>Gelidium corneum</i> var.? (Huds.) Lamour.	Do.
<i>Gelidium filicinum</i> ?	Limu loloa or limu ekahakaha.
<i>Gelidium latifolium</i> ? Born	Limu loloa.
<i>Gelidium micropterum</i> ?	Do. ^b
<i>Gelidium pulvinatum</i> ?	Do.
<i>Gelidium pusillum</i> ?	Do.
<i>Gelidium</i> sp.?	Limu kekuwelu or limu kuwelu.
<i>Gracilaria coronopifolia</i> , J. Ag.	Limu manauea.
<i>Grateloupia filicina</i> (Wulf.), Agh.	Limu pakaeleawaa or limu ^b huluhulu-waena.
<i>Griffithsia</i> sp.?	L. moopuna, limu ka-lipoa, ^c or limu aupupu.
<i>Gymnogongrus vermicularis americana</i> , J. Ag.	<div style="display: inline-block; vertical-align: middle; font-size: 3em; line-height: 1;">{</div> <div style="display: inline-block; vertical-align: middle; margin-left: 0.5em;"> Limu uualoli.^d Limu ekahaekaha. Limu koelele or koele. Limu awikiwiki. Limu nei. </div>
<i>Gymnogongrus diciplinalis</i> (Bory.), J. Ag.	
<i>Haliseris pardalis</i> ^e	
<i>Haliseris plagiogramma</i> , Mont.	
<i>Halymenia formosa</i>	Limu lipoa.
<i>Hydrodictyon reticulatum</i> (Linn.) Lagerh.	Do.
<i>Hypnea nidifica</i> , J. Ag.	Limu lepeahina (very rare).
<i>Hypnea armata</i>	Limu palawai.
<i>Laurencia papillosa</i> (Forst.), Grev.	Limu huna.
<i>Laurencia pinnatifida</i> (Gmel.), Lamour.	Do.
<i>Laurencia pinnatifida osmunda</i>	Limu maneoneo ^f or limu lipeepee.
<i>Laurencia perforata</i>	L. maneoneo, limu olipeepee, or limu lipee.
<i>Laurencia obtusata</i>	Limu lipeepee or lipee.
<i>Laurencia virgata</i> (Ag.), J. Ag.	Do.
<i>Laurencia</i> sp.?	Do.
<i>Liagora decussata</i>	Limu maneoneo or limu lipuupuu.
<i>Nais major</i> , All	Limu puaki.
	Limu kala-wai. ^g

^a On Maui it is sometimes called limu pipilani. Limu eleele is the name for most all the *Enteromorphas* of these islands.

^b This name is in very general use on Hawaii and Maui, but both names are common on Oahu.

^c This alga is considered a delicacy on Maui and southern Hawaii, but is very scarce and spoils very soon, so have not been able to secure enough to identify the species.

^d This limu is usually called limu uualoli, but the other names are used in certain localities.

^e This is very rare, only washed ashore occasionally, but resembles the other limu lipoa, hence the name.

^f The several species of *Laurencia* are generally called limu maneoneo, if coarse and short, and limu lipeepee if finer and longer. Limu lipee is an abbreviation, while limu lipuupuu has only local use in places on Hawaii and Maui.

^g This is not an alga, but a flowering plant sold in the market as a limu, probably because it grows in fresh water and resembles the common limu kala from the sea.

Scientific names.	Native names.
<i>Nitophyllum?</i>	Limu haula. ^a
<i>Pithophora affinis?</i> Nordst.....	Limu palawai ^b or limu lipalawai.
<i>Pithophora polymorpha</i>	Do.
<i>Polyopes?</i>	Limu luau. ^c
<i>Polysiphonia mollis</i>	Limu pualu ^d or limu hawane.
<i>Porphyra leucosticta</i> , Thurst.....	Limu luau or limu lipahee. ^e
<i>Pterocladia capillacea</i> (Gmel.), Bornet.....	Limu loloa. ^f
<i>Sargassum echinocarpum</i> , J. Ag.....	Limu kala.
<i>Sargassum cymosum</i> , Ag.....	Do.
<i>Sargassum polyphyllum</i> , J. Ag.....	Do.
<i>Spiridia spinella</i>	Limu hulupuaa. ^g
<i>Spirogyra</i> sp. (probably several) ^h	Limu palawai, limu nehe, and limu polao.
<i>Stigeoclonium amœnum</i> , Kg.....	Limu huluilio. ⁱ
<i>Stigeoclonium</i> sp?.....	Limu palawai or limu lipalawai.
<i>Streblodocladia?</i>	Limu hawane. ^h
<i>Ulva fasciata</i> , ^j Delile.....	Limu pahapaha or limu palahaloha.
<i>Ulva lactuca rigida</i> (Agh.) Le Jolis.....	Limu lipahapaha.
<i>Ulva lactuca lacinata</i> (Wulf.) J. Ag.....	Limu lipalahalaha, limu pakaea.
<i>Valonia utricularis</i>	Limu lipuupuu.

^a Very rare, only one small specimen obtained from a native on Maui.

^b Most all the edible green fresh-water algæ are called lipalawai or polawaie, and there are perhaps a half dozen species in the mountain streams that are known by these names.

^c A single small specimen sent by native on Maui, similar to *Porphyra*.

^d Used by but few Hawaiians for food; not popular.

^e Reported only from two islands and scarce; called limu luau on Kauai and limu lipahu on Hawaii.

^f This species often called limu loloa on Maui and Kauai.

^g Not in general use, but eaten in the southern part of Hawaii.

^h Imperfect and immature specimens, so could not be positively identified.

ⁱ This grows in brackish water pools by the sea and is eaten by only a few Hawaiians.

^j These three species seem to be indistinguishable by the natives, and the different islands and localities have various forms of the name, but limu pakaea is only in use on Hawaii.